IX. SPECIAL STUDIES

A. Power Plant Plumes

1. Introduction

During the 1973 experimental program, a few days were allocated for the sampling of point source plumes. The sampling was exploratory in nature and was performed to develop and test sampling procedures as well as to study the properties of the plume. Two power plants were selected for tests. The plume from the Ormond Beach power plant adjacent to the Point Mugu Naval Air Station was sampled on July 3, 1973, and the plume from the Moss Landing power plant was sampled on January 9 and 10, 1974.

2. Ormond Beach, July 3, 1973

The Ormond Beach power plant is located on the coast just west of the Point Mugu Naval Air Station and about five miles south of Oxnard, California. The plant has a total capacity of 1600 megawatts and two stacks, each about 230 feet tall. The plume was sampled between 1345 and 1400 PDT on July 3, 1973. Since the flight was basically a test flight, no prior arrangements were made to obtain ground data, and only minimal data other than those taken by the aircraft were obtained.

Figure IX-1 shows the location of the plant and the plume outline during the sampling period. The two dotted lines indicate the flight paths through the plume. Two passes were made through the plume at each of the two distances with the NO_x monitor set for NO on one pass and for NO_x on the other.

The meteorology for the day was typical of summer subsidence conditions. A strong subsidence inversion was based at about 1600 feet msl near the coast and extended to about 2100 feet. The inversion was reinforced by the undercutting sea breeze and marine inversion near the coast and was slightly weaker and higher inland. The inversion provided a strong lid to limit vertical mixing. Winds at the surface at Point Mugu during the sampling period were onshore (westerly) at about 7 mph, but winds aloft observations down the coast at Los Angeles Airport and inland at El Monte indicated that the sea breeze decreased with altitude and that the wind speeds within the inversion layer were only 2-3 miles/hour.

Figure IX-2 is a vertical profile taken shortly before the plume sampling at Ventura County Airport, about five miles northwest (upwind) of the plant. The radiation inversion is evident in the figure, and the marine inversion can be seen from about 500 to 1300 feet msl. A layer of aged pollution exists within the marine inversion, and there is

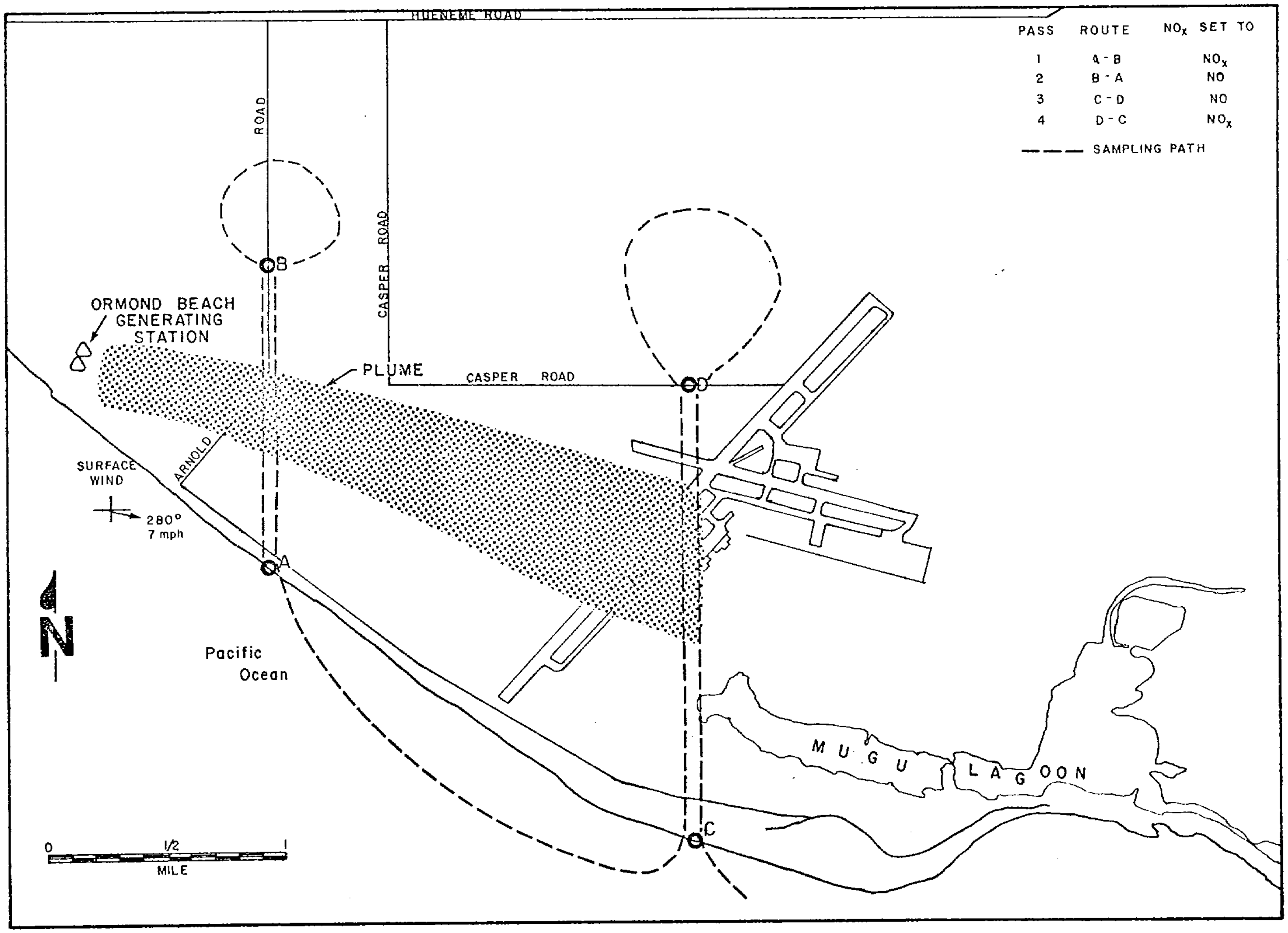


Fig. IX-1. LOCATION OF ORMOND BEACH GENERATING STATION AND OUTLINE OF PLUME, 1345 PDT, JULY 3, 1973

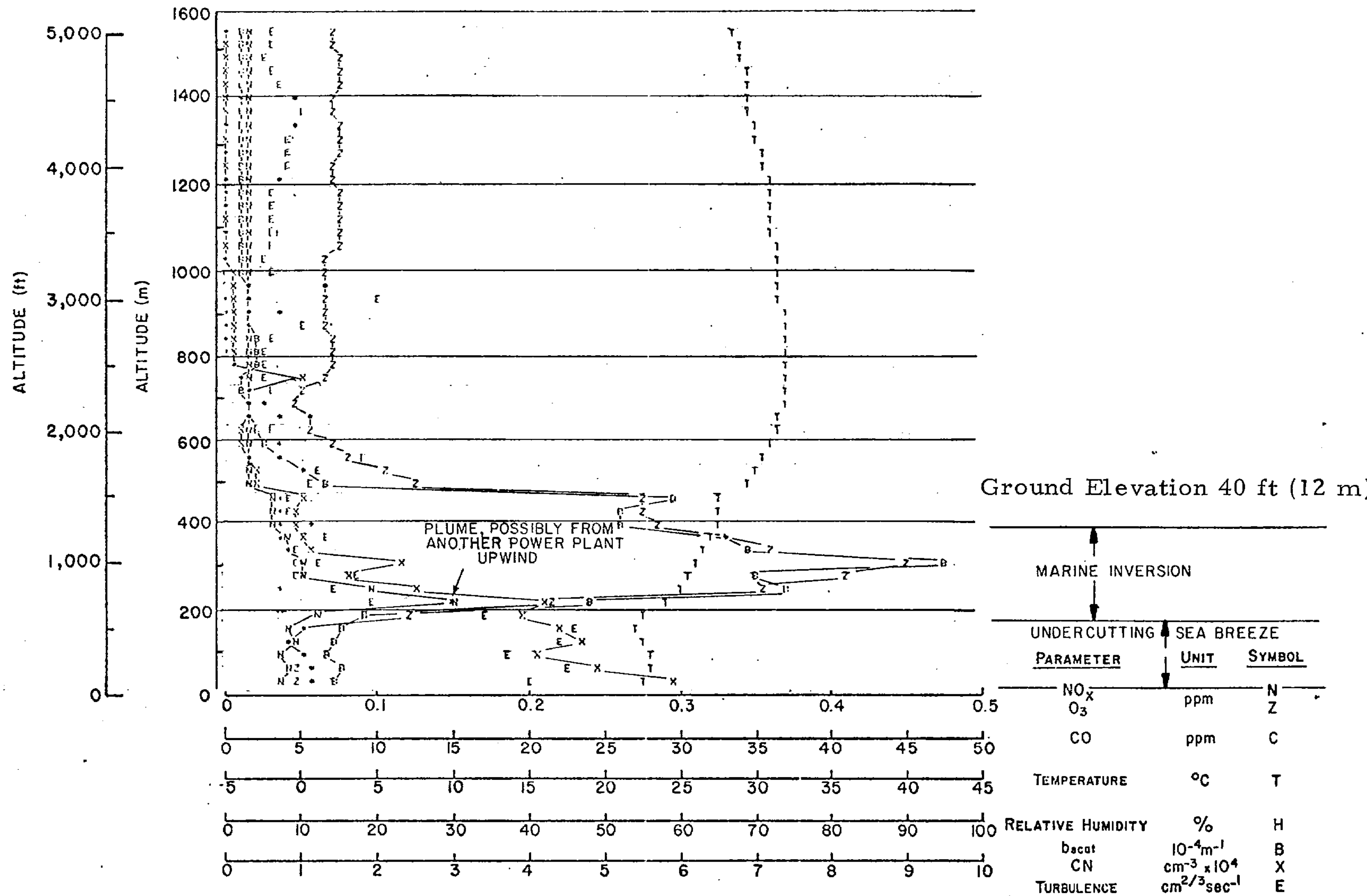


Fig. IX-2. VERTICAL PROFILE OVER VENTURA, 1331 PDT, JULY 3, 1973 evidence of a plume at the bottom edge of the marine inversion. The sea breeze is ventilating the area near the surface.

The dense layer aloft in Fig. IX-2 is curious in that it is isolated from the surface and is lower than the mountains surrounding the Oxnard plain. Light winds aloft make transport from other areas difficult. A possible source of some of the pollutants in the layer may be plumes from facilities in the Oxnard-Ventura area with enough buoyancy to penetrate into the inversion layer. This is indicated in Fig. IX-2 by the small NO_x peak within the inversion layer. This peak is probably due to another power plant directly upwind of the airport. Since the winds were light aloft, and the sunlight intense, effluents penetrating into the stable air would have had plenty of time to react and possibly form the high levels of ozone and other photochemical products present.

Figure IX-3 is a plot of the data from the first pass through the Ormond Beach plume (path A-B in Fig. IX-1). This traverse was made at about 0.9 miles downwind of the plant at 150 feet msl which is slightly into the marine inversion. It is clear from the figure that the plume penetrates at least a short distance into this stable layer. The full vertical extent of the plume was not identified since only a limited altitude range was sampled at each location.

At the time of the sampling, both units of the generating station were operating with one burning oil and the other burning gas. The gas unit was generating about 700 megawatts while the oil unit was generating 560 megawatts. The double plume structure from the two stacks is evident in Fig. IX-3. A double peak can be seen in the NO_x, condensation nuclei, and turbulence traces as well as a double ozone deficit due to scavenging by NO. Only a single SO_2 peak is seen since only the oil-fired unit was emitting SO_2. One peak is definitely larger than the other at this elevation, probably because of differences in plume height due to the different loadings and fuel.

Some caution must be taken in using Fig. IX-3 to obtain quantitative information. No instrument time response or transfer function corrections were made in plotting the data, and it is possible that concentrations in the plume could be higher than indicated. The SO_2 instrument (a Theta-Sensor electrochemical unit) was not operating correctly. Although it was calibrated properly, it experienced long delay times in responding, and the time response to 90 percent was quite slow. The SO_2 peak in Fig. IX-3 was shifted back to coincide with the

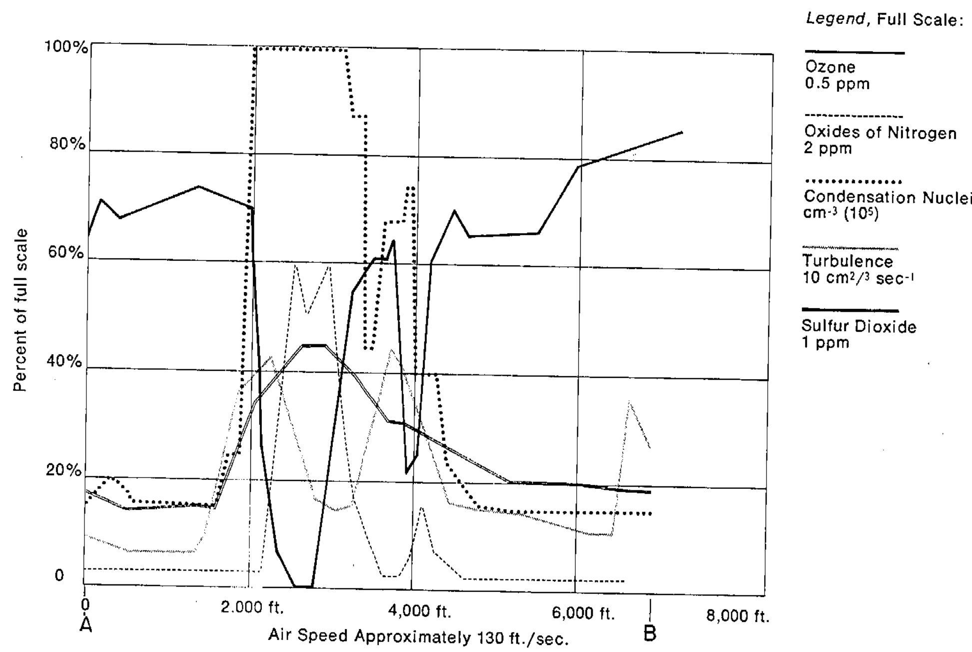


Fig. IX-3. TRAVERSE OF ORMOND BEACH PLUME (FROM A TO B) 1344 PDT, JULY 3, 1973, 650 FT msl

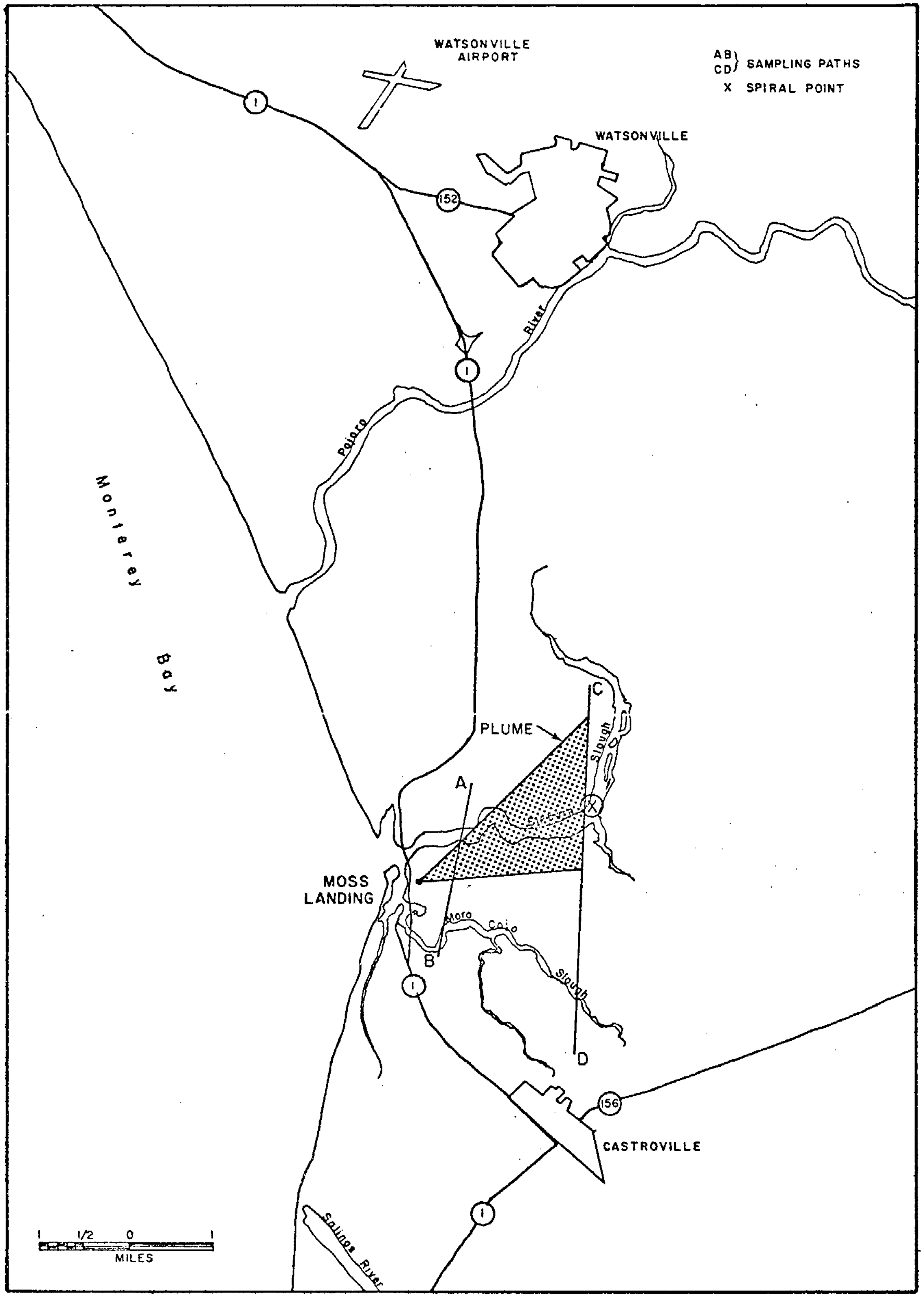


Fig. IX-5. MOSS LANDING PLUME LOCATION AND TRAVERSE PATHS ON THE AFTERNOON OF JANUARY 9, 1974. ONE SPIRAL WAS MADE AT SALINAS AIRPORT AND ONE AT POINT X

The maximum NO_x concentrations from each traverse are plotted in Fig. IX-6 as functions of altitude and downwind distance. The resulting plume contour map shows the plume dispersing rapidly as it moves downwind, as was evidenced further by the more detailed perpendicular cross-sections of the plume. Maximum measured NO_x concentrations were 0.46 ppm 1/2 mile downwind and 0.11 ppm 2-1/2 miles downwind.

A similar mapping of SO_2 maximum concentrations is shown in Fig. IX-7. 0.12 ppm and 0.02 ppm were the maxima 1/2 and 2-1/2 miles downwind, respectively. A note of caution must be expressed with regard to all the SO_2 data. This instrument has a slow response time (~ 20 seconds to 90 percent) and has a sensitivity of about 0.001 ppm. It was often operating near its limit of sensitivity. Thus, data on the order of 0.01 ppm will have a large error bound. Other SO_2 data taken close to the plant may be lower than the true concentrations because of the slow transient response.

Figures IX-6 and IX-7 indicate that the plume had an effective stack height roughly between 1500 and 2000 feet msl and that it dispersed rapidly a short distance downwind.

In studying figures such as IX-6 and IX-7, it should be kept in mind that these figures are composites generated over a long period of time and are not true "snapshots" of the plume. If conditions remain steady state, these contours are accurate representations; but if the stability or plant operating conditions change, the maps may be distorted.

c. January 10, 1974 Morning Sampling

(1) Surface Meteorology

Offshore flow, with a southerly component (about 145° at 3 mph) prevailed in the Moss Landing area in the early and mid-morning during the sampling periods, but a northwesterly sea breeze became dominant by 1300 (PDT), accompanied by scattered to broken stratus. Visibilities increased from 15-20 miles at 0900 to 25-30 miles by 1300. Surface temperatures during the morning flight increased from the high 40's to the lower 50's.

At 0930 PDT, a spiral above the Salinas Airport showed a surface-based inversion to 400 feet followed by an isothermal layer to 1300 feet and a neutral atmosphere to 3600 feet, where another inversion began.

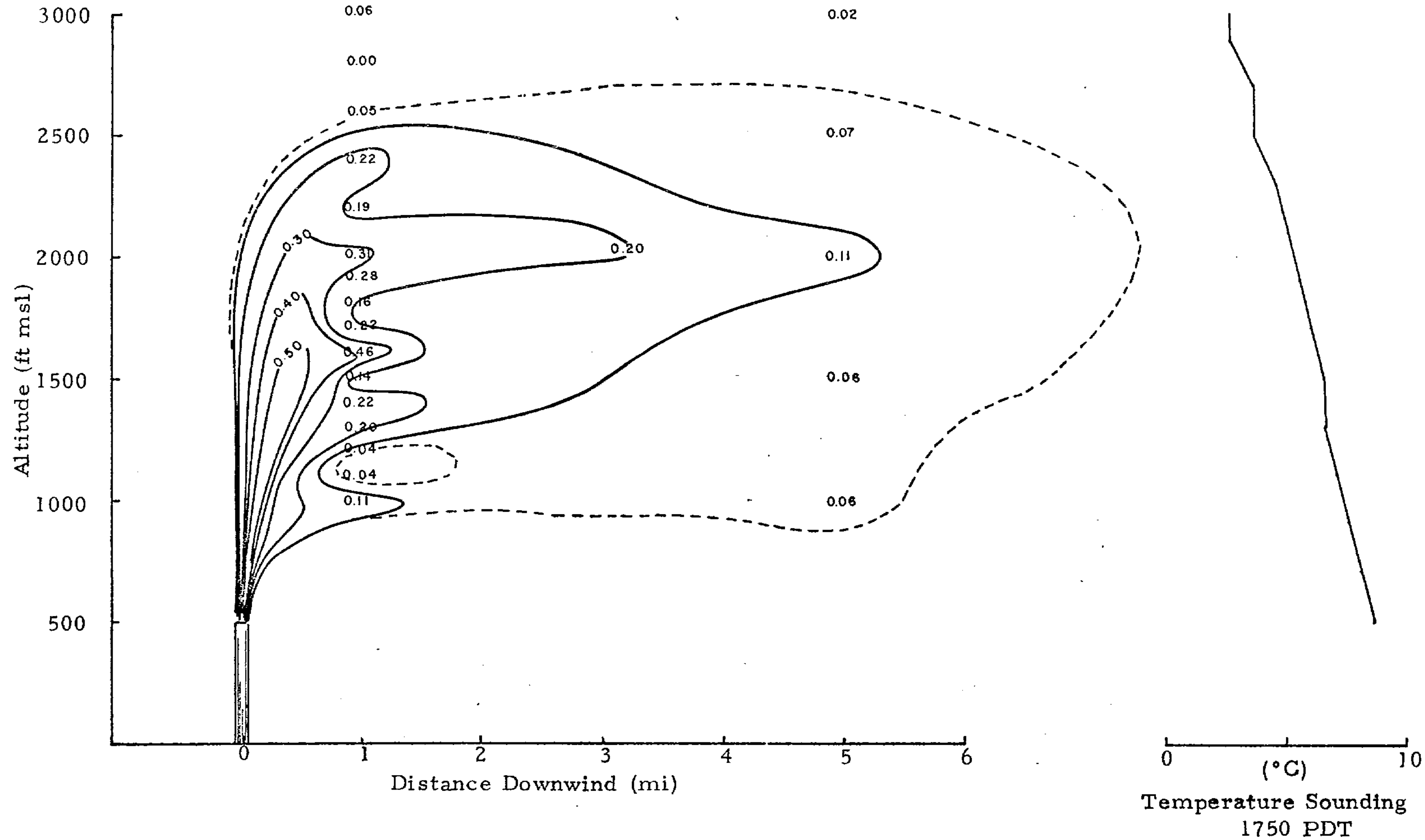


Fig. IX-6. MOSS LANDING PLUME PROFILE SHOWING MAXIMUM NO_x CONCENTRATIONS (ppm), 1550-1740 PDT, JANUARY 9, 1974

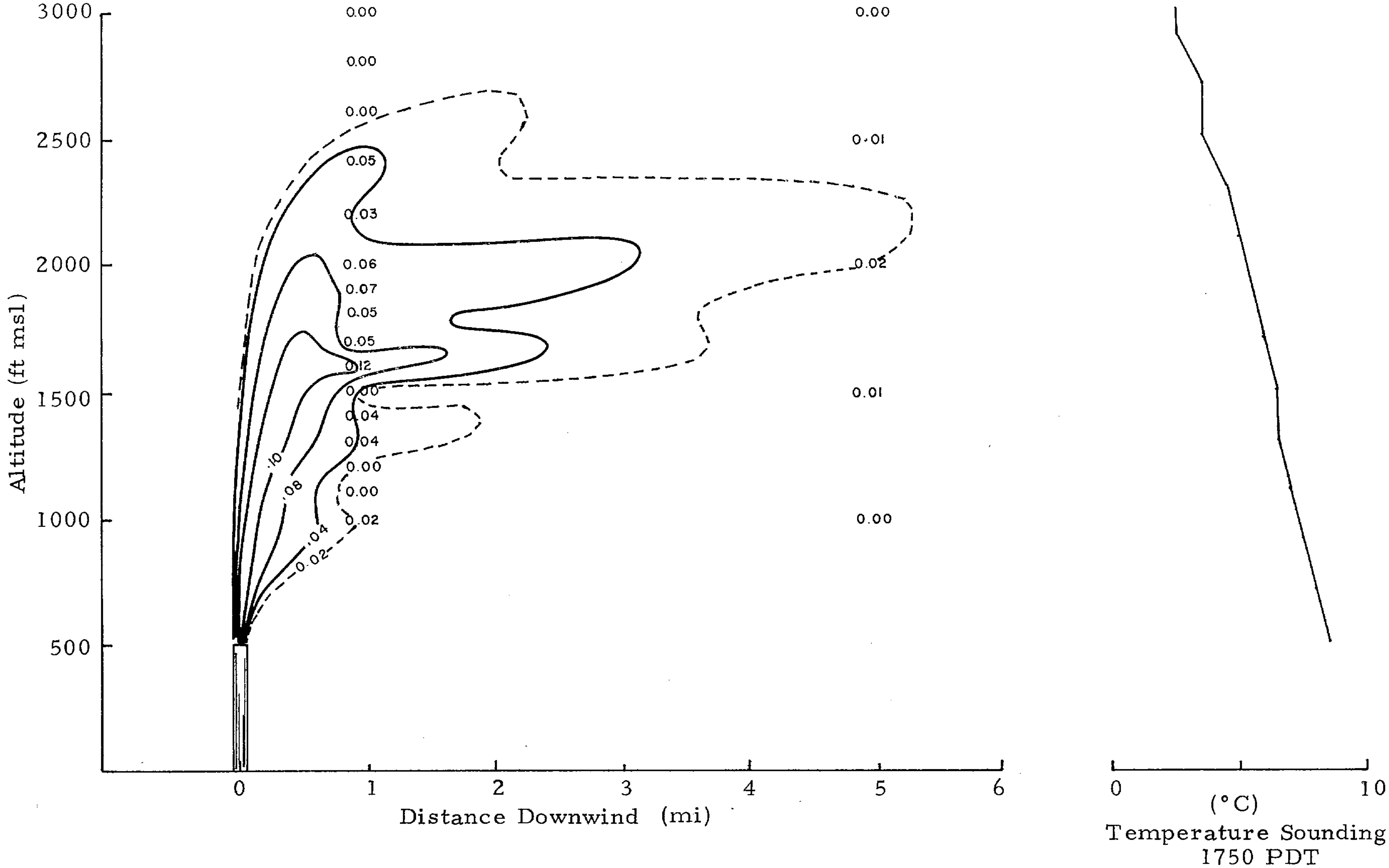


Fig. IX-7. MOSS LANDING PLUME PROFILE SHOWING MAXIMUM SO_2 CONCENTRATIONS (ppm), 1550-1740 PDT, JANUARY 9, 1974

(2) Plume Characteristics

At Moss Landing, the plume was located offshore, to the west of the power plant. Sampling paths crossing the bay were set up to traverse the plume at distances of 1 and 2-3/4 miles downwind from the plant. At one mile downwind, traverses were made at 500 feet (msl) and at 200 foot altitude intervals from 800 to 2600 feet. Six traverses were made along the second path; however, the wind direction shifted gradually during this series of traverses with the result that the plume was found further to the north, and thus further from the plant, on each successive traverse. The traverse paths and the shifting plume position are shown in Fig. IX-8. During the sampling, both units 6 and 7 were operating at about 450 megawatts with NO_x concentrations in the stacks of about 200 ppm.

A profile of the plume showing maximum NO_x concentrations from each traverse is shown in Fig. IX-9. The data from the second set of traverses have been plotted at their straight-line distances from the plant, although the actual distance traveled by the plume might be greater due to the shifting wind direction.

Also shown in Fig. IX-9 are the temperature profiles at the beginning and the end of the flight. Initially, the plume had risen up through the isothermal layer (400 feet-1300 feet) and into the neutral layer above. During the flight, the temperature structure changed, resulting in a smaller isothermal layer between 1000 and 1400 feet and a neutral lapse rate elsewhere up to 300 feet. The plume height was observed to increase correspondingly toward the end of the sampling period during the "2-3/4" mile traverse.

A similar contour plot of maximum SO_2 concentrations is shown in Fig. IX-10.

Figure IX-11 is a cross-section of the plume perpendicular to the wind direction made from the one-mile traverses showing NO_x concentration contours. Under the stable conditions experienced at the time of this mapping, the plume was smaller and more compact than on the previous afternoon. The maximum recorded NO_x concentration was 0.59 ppm. The major part of the plume extended between altitudes of 900 and 1800 feet, with smaller portions found up to 3200 feet and at 500 feet (msl). The 1400-foot traverse, one mile downwind, is shown in Fig. IX-12. The NO_x concentrations which are greater than full scale in Fig. IX-12 have been more accurately determined from the data logger records, in developing Fig. IX-11.

The traverse shown in Fig. IX-12 indicates a well-defined plume structure similar to that seen at Ormond Beach with peaks of NO_x, SO_2, and condensation nuclei and an ozone deficit, indicating

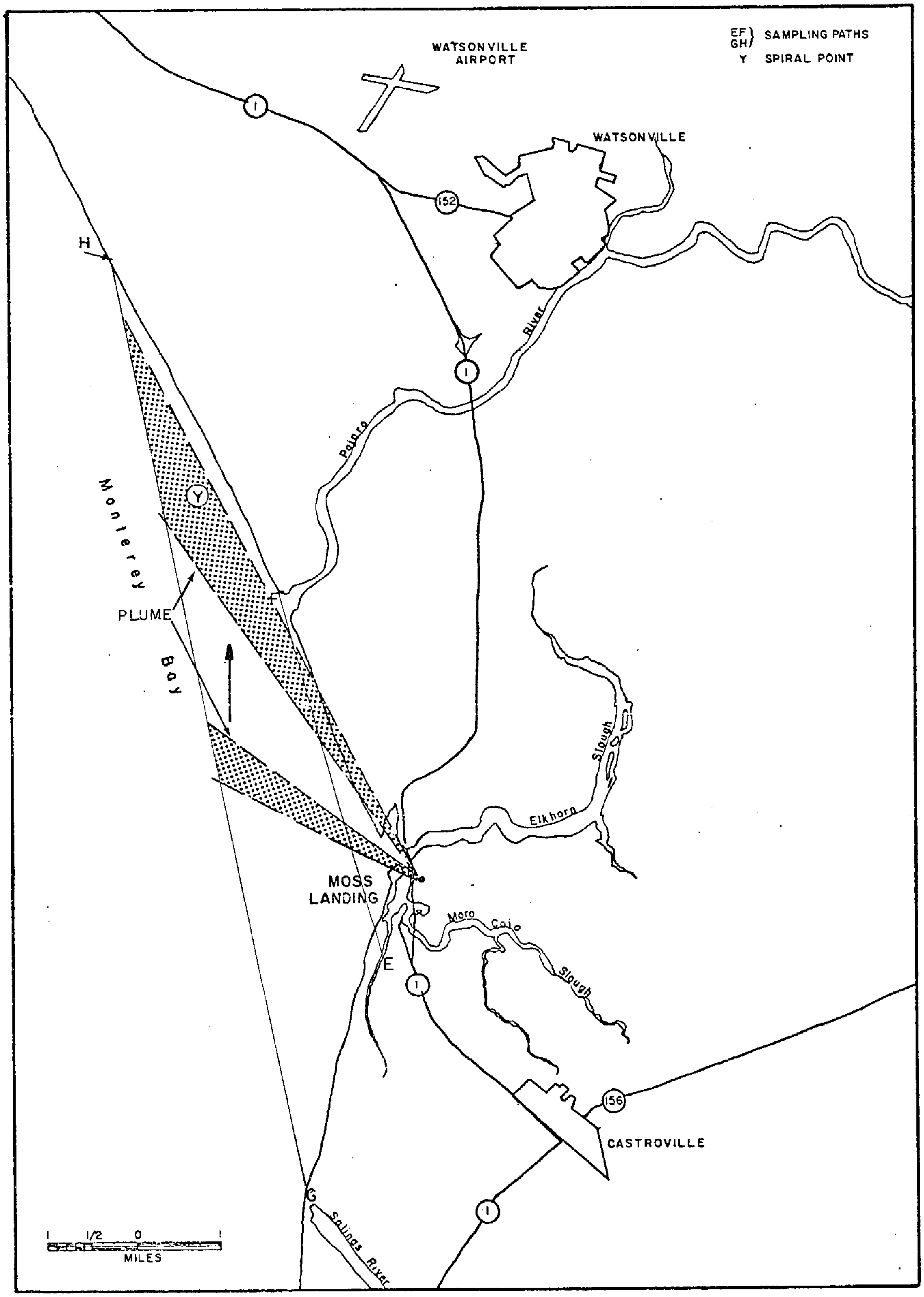
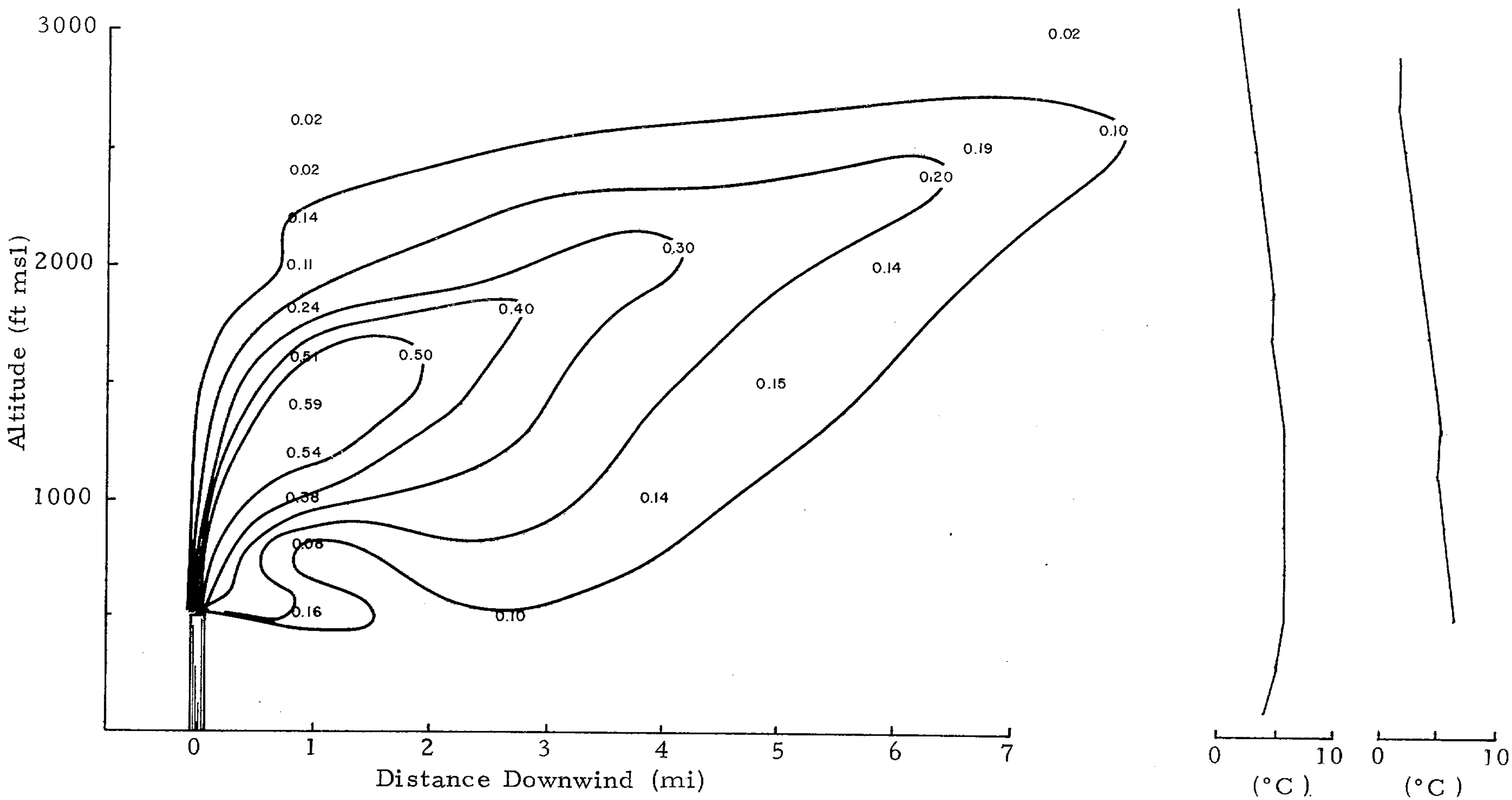


Fig. IX-8. MOSS LANDING TRAVERSE PATHS AND SHIFTING PLUME LOCATION ON MORNING OF JANUARY 10, 1974. ONE SPIRAL WAS MADE AT SALINAS AIRPORT AND ONE AT POINT Y



Temperature Soundings
0940 (PDT) 1205 (PDT)

Fig. IX-9. MOSS LANDING PLUME PROFILE SHOWING MAXIMUM NO_x CONCENTRATIONS (ppm), 0950-1150 PDT, JANUARY 10, 1974. TEMPERATURE STRUCTURE AT THE BEGINNING AND END OF THE FLIGHT IS ALSO SHOWN.

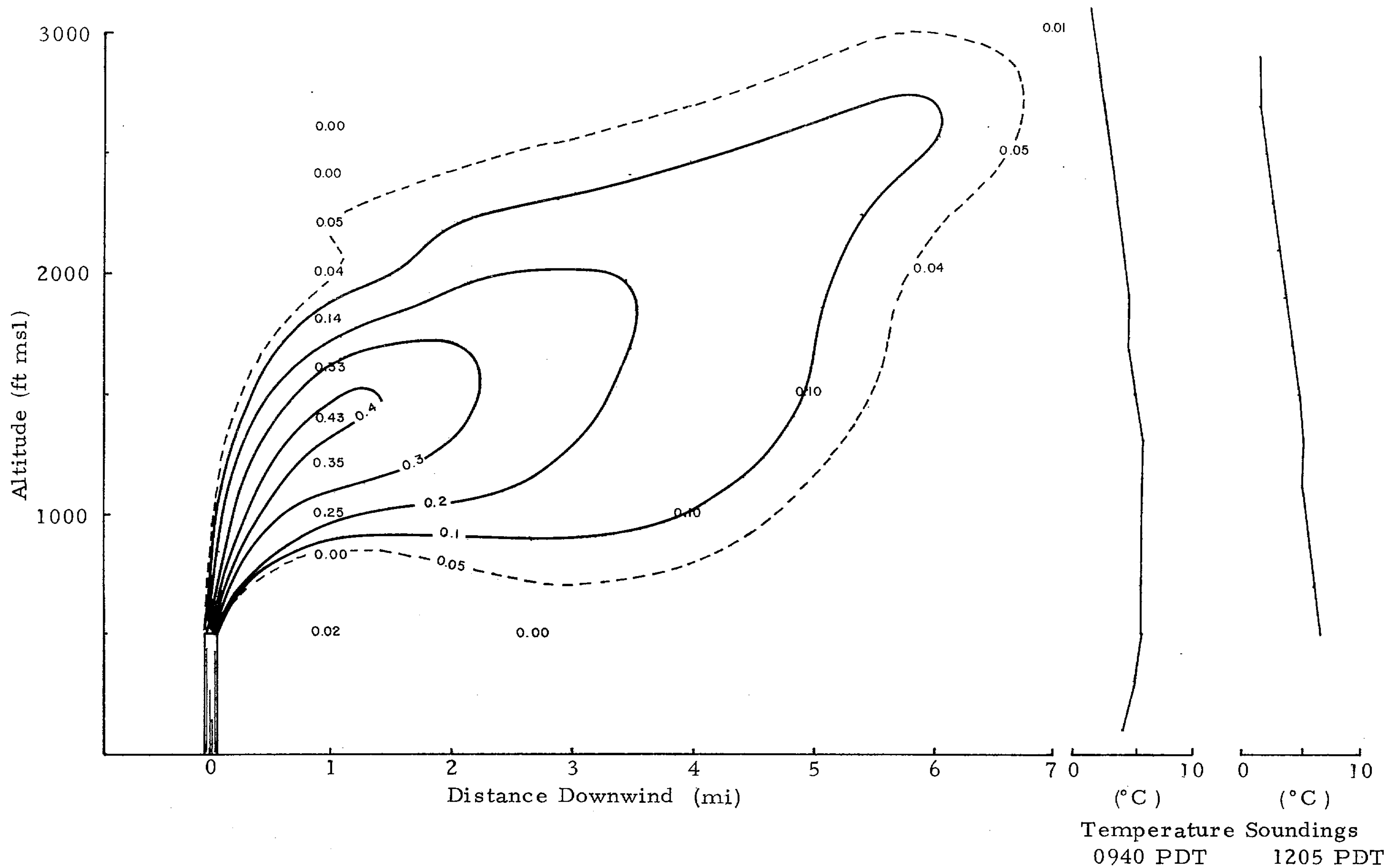


Fig. IX-10. MOSS LANDING PLUME PROFILE SHOWING MAXIMUM SO_2 CONCENTRATIONS (ppm), 0950-1150 PDT, JANUARY 10, 1974

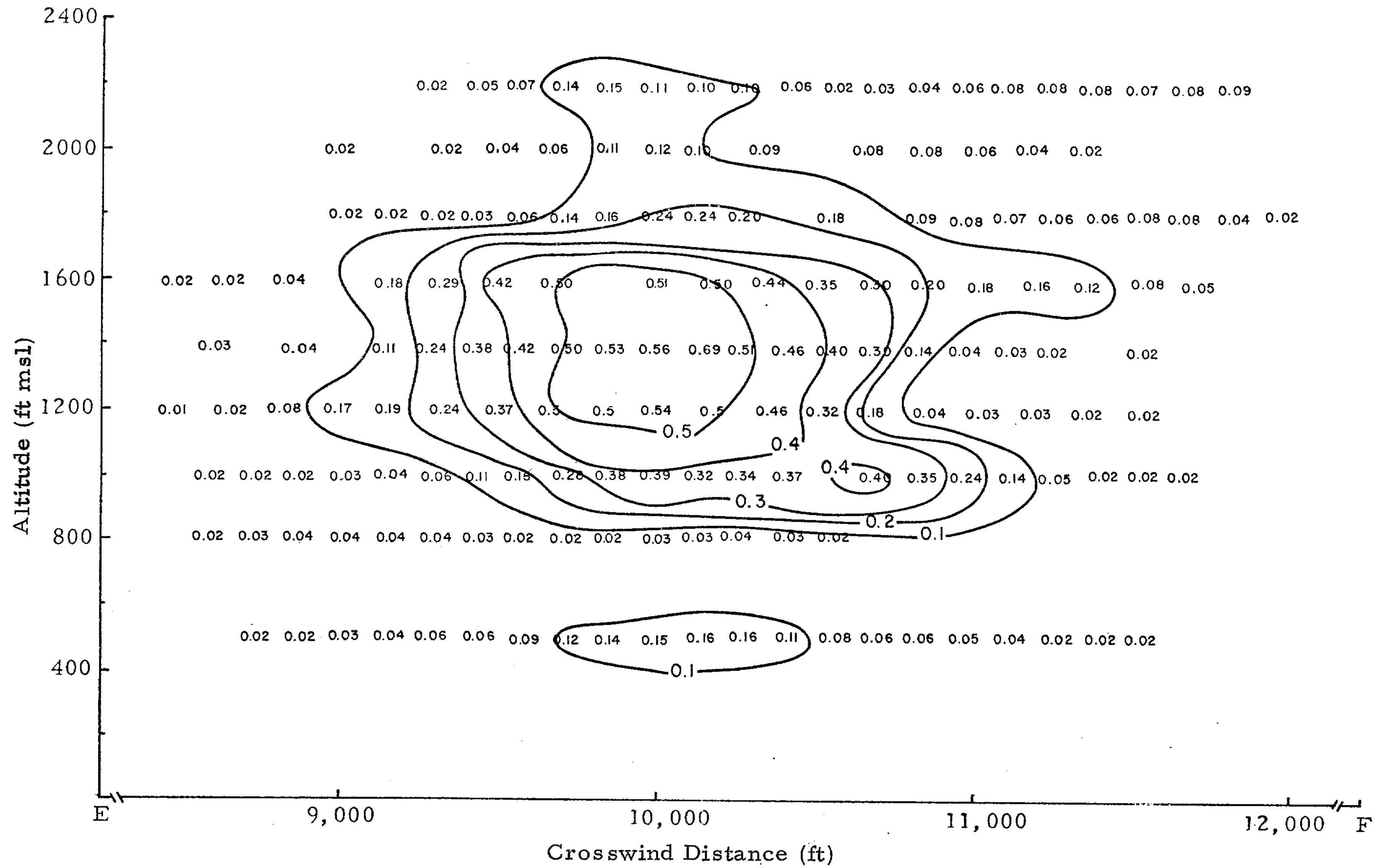


Fig. IX-11. MOSS LANDING PLUME CROSS-SECTION, ONE MILE DOWNWIND, SHOWING NO_x CONCENTRATION CONTOURS (ppm), 1000-1045 PDT, JANUARY 10, 1974

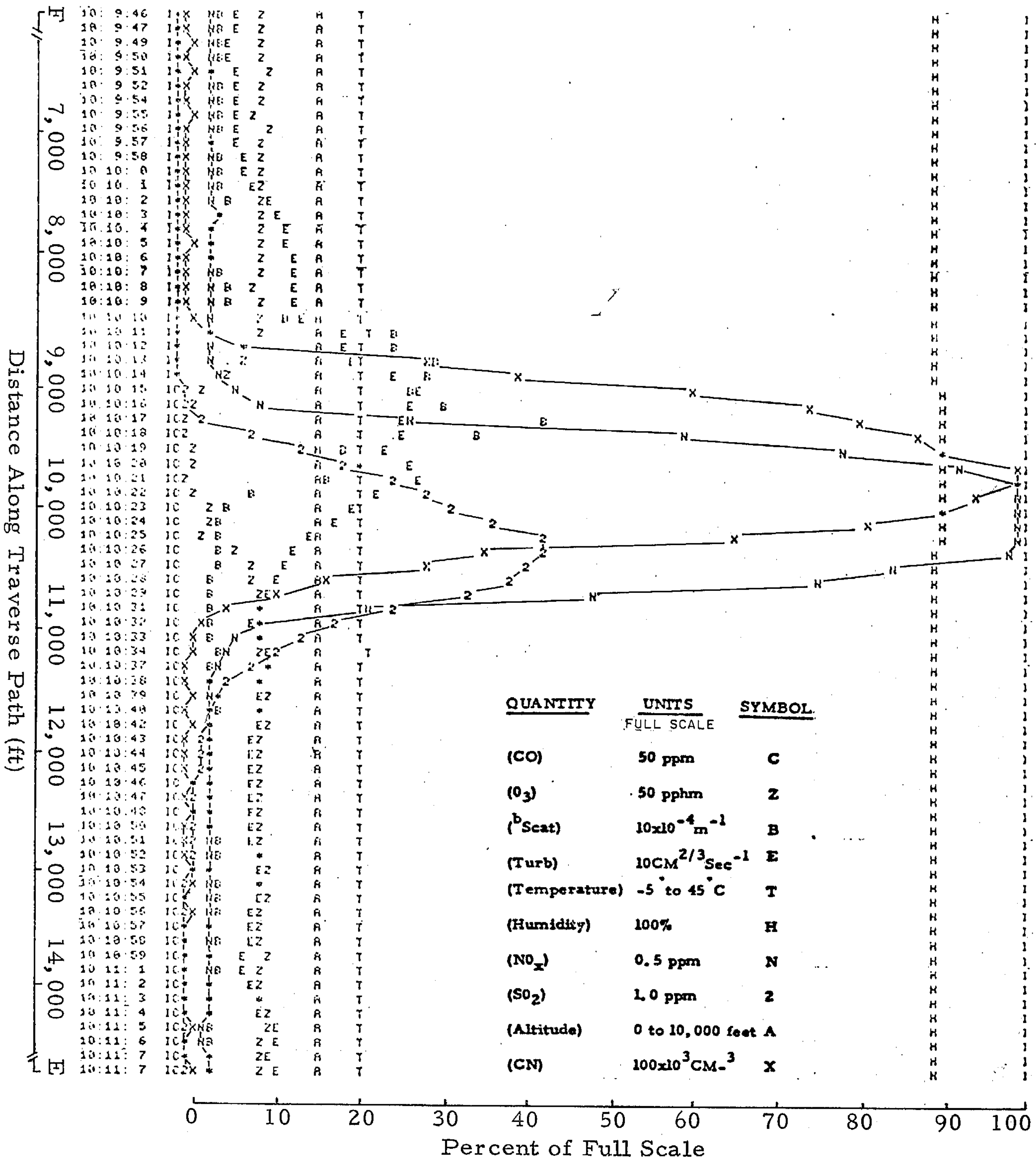


Fig. IX-12. TRAVERSE THROUGH MOSS LANDING PLUME CENTER, ONE MILE DOWNWIND, AT 1400 FT, 1010 PDT, JANUARY 10, 1974 the plume. A major difference, however, is that this plume is surrounded by clean air with an ozone level of about 0.04 ppm.

From the figures presented, it is evident that the stable conditions prevalent during this sampling period resulted in a better-defined plume than on the 9th with higher concentrations downwind. NO_x concentrations greater than 0.2 ppm were still being measured at about six miles downwind of the plant. These high concentrations were not, however, ventilated to the ground. Even though the plant was operating at a higher load than the evening before, the effective plume height at the beginning of the sampling period (1-mile traverses) was about 1500 feet msl, or slightly lower than on the 9th, probably due to the more stable thermal structure. By the time of the "2-3/4" mile traverses, the stability had lessened, and the plume height had increased.

d. January 10, 1974, Afternoon Sampling

(1) Surface Meteorology

The afternoon onshore sea breeze started out westerly and shifted to northwesterly during the sampling period. The winds at the Moss Landing plant varied from 276° at 2 mph to 315° at 5 mph. A stratus layer was present at an estimated 3500 feet, and visibilities along the coast were about 15 miles. Surface temperatures were in the low 50's (°F). The preliminary spiral above Salinas Airport showed a neutral temperature lapse rate to 3200 feet.

(2) Plume Characteristics

The plume was found to the ENE of the plant. Three traverse paths were used to map the plume: 1.3, 2.5, and 3.7 miles downwind. During the sampling, both units 6 and 7 were operating at 310 megawatts, and stack NO_x concentrations were between 160 and 210 ppm.

Figures IX-13 and IX-14 are plume profiles showing maximum NO_x and SO_2 concentrations, respectively. Comparison of these data to those obtained on the previous afternoon shows that the plume was again dispersing fairly rapidly, although the plume was a bit better defined than that found previously and was not spread out vertically as much. At 3.7 miles, concentrations had diminished considerably from the morning flight due to the decrease in stability, and possibly to an increase in wind speed aloft. The maximum concentrations recorded were 0.23, 0.10, and 0.08 ppm NO_x at downwind distances of 1.3, 2.5, and 3.7 miles, respectively, and 0.09, 0.06, and 0.02 ppm SO_2 for the same distances.

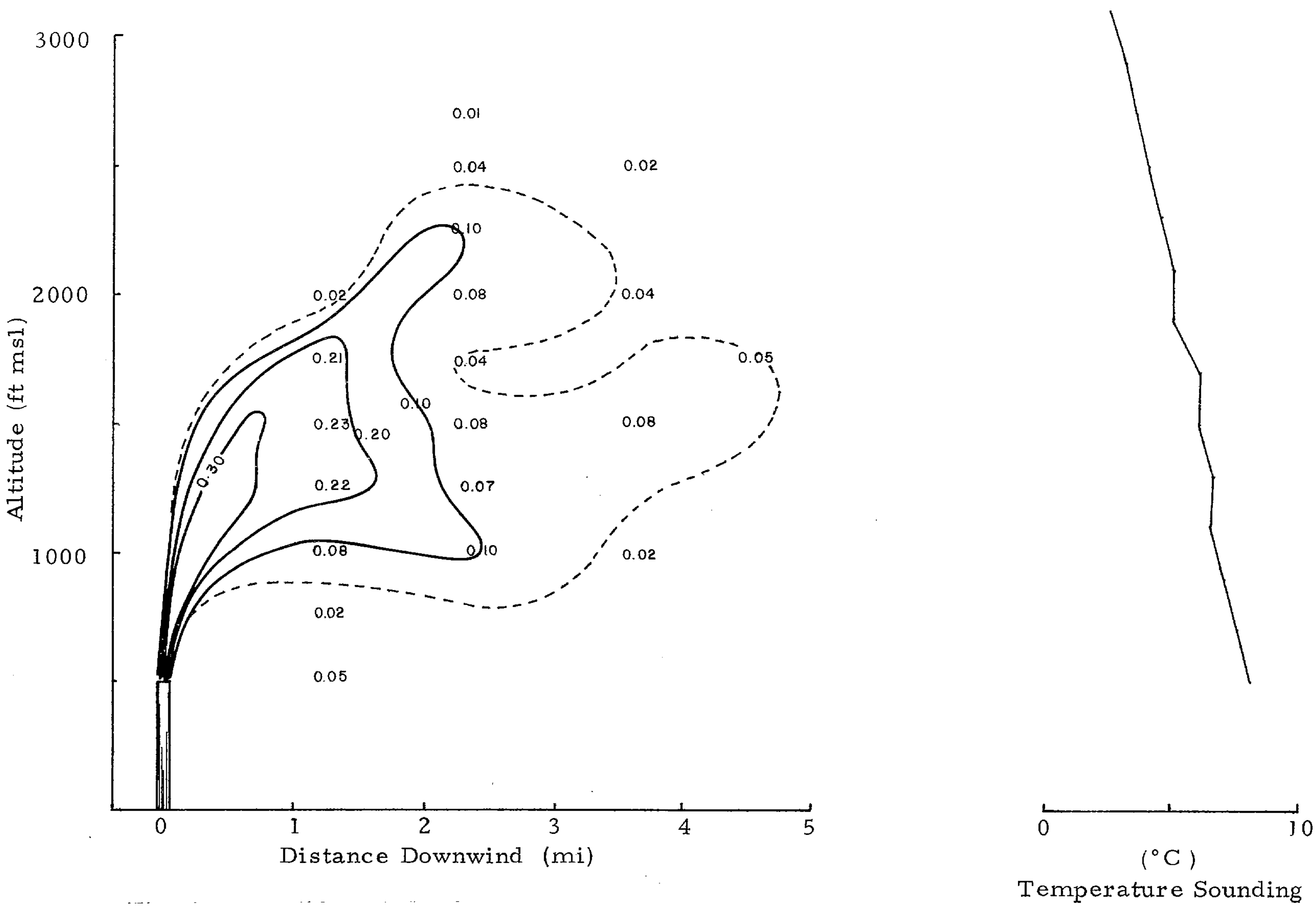


Fig. IX-13. MOSS LANDING PLUME PROFILE SHOWING MAXIMUM TRAVERSE NO_x CONCENTRATIONS (ppm), 1355-1545 PDT, JANUARY 10, 1974

e. NO and NO_x Concentrations

On the afternoon flight of 10 January, one traverse at each downwind distance was repeated, measuring NO instead of NO_x. The peak NO_x or NO readings from the original and repeated traverses were compared and normalized to the peak SO_2 readings. (Normalization was necessary due to fluctuations in plume concentrations and variations in sampling position.) The results are shown in the following table.

TABLE IX-II

NO, NO_x RATIOS

	Distance Downwind (miles)	NO_x Traverse Concentrations (ppm)	NO Traverse Concentrations (ppm)	NO Concentration (Normalized to NO_x Traverse) (ppm)	NO/NO_x (%)
peak $NO_{(x)}$ / peak SO_2	1.3	0.220 / 0.09	0.100 / 0.06	$\frac{0.09}{0.06} \times 0.100 = 0.150$	68
peak $NO_{(x)}$ / peak SO_2	2.5	0.085 / 0.04	0.025 / 0.01	$\frac{0.04}{0.01} \times 0.025 = 0.100$	118
peak $NO_{(x)}$ / peak SO_2	3.7	0.080 / 0.02	0.035 / 0.01	$\frac{0.02}{0.01} \times 0.035 = 0.070$	88

The results obtained by this method are quite approximate due to the crudeness of the normalizing process and to the large error introduced by working with relatively small concentrations. The results indicate that the majority of the oxides of nitrogen emissions are in the form of NO. The uncertainty in the results is too large to permit calculation of the NO to NO_x conversion rate, but it appears to be fairly low under these conditions. It is obvious from the data, however, that the conversion rate is much lower than at Ormond Beach. Thus, the oxidant and other pollutant background levels, and possibly the meteorology as well, have a strong influence on the plume chemistry.

f. Plume Sulfate Concentrations

On each set of traverses, a pair of back-to-back glass fiber filters was operated at one of the spare sampling inlets to collect plume particulate matter for sulfate analysis. The filters were analyzed by P. Roberts of the California Institute of Technology using an aerosol vaporization technique. Discs cut from the filter are heated to about 1100 °C, vaporizing the aerosol into a flowing airstream which passes into a flame photometric detector for sulfur (Meloy SA-160). The output is electronically integrated to obtain the total vaporized sulfur in the sample. Sulfur compounds such as $(NH_2)_2SO_4$ or H_2SO_4 which vaporize and decompose below 1100 °C are detected by this method. The detection limit is approximately 0.01 μg of sulfate (assuming all sulfur to be in the form of sulfate) per filter. The purpose of using two filters is to determine the amount of SO_2 absorbed by the filters. (Significant quantities are absorbed when plume concentrations of SO_2 are high.) The total sulfur detected on the backup filter is subtracted from the quantity found on the first filter to obtain the sulfate concentration. This procedure assumes that all the aerosol is collected on the first filter and that the two filters absorb SO_2 equally.

Concentrations of 0.01 to 0.02 μg sulfate were found on most of the filters. There is a high uncertainty in these concentrations, since they are so near the detection limit of the method. One filter contained 0.21 μg sulfate but was thought to have been contaminated and was discarded from further consideration. To determine the extent to which conversion of SO_2 to sulfate occurred in the plume, the total amount of sulfate collected on each filter was compared to the total quantity of SO_2 which passed through the filter. In this comparison, the total SO_2 sampled through the filter was determined by integrating the SO_2 plume concentrations (as measured by the SO_2 monitor) and multiplying the integrated total by the flow rate through the filter:

$$\text{Total } SO_2 \text{ sampled} = \int_{\text{Time in plume}} SO_2\,(\text{ppm})\,dt \times \text{filter flow rate} \times 2.85 \times 10^6\ (\text{gm/L})/\text{ppm}$$

$$(1\ \text{ppm } SO_2 = 2.85 \times 10^6\ \text{gm/liter at S.T.P.}).$$

For comparison on a molecular basis, SO_4 is taken as SO_2 (i.e., SO_4 quantities are multiplied by $\frac{64}{96}$).

The SO_4 (as SO_2) to SO_2 ratios for the Moss Landing study ranged from 0.2 to 1.0 percent. Since the sulfate quantities were so near the detection limit, these values should be taken as an upper limit of the extent of conversion in the plume.

Calculation of reaction rates for the conversion process using downwind distances and wind speeds as measured at the power plant to determine reaction times gives results ranging from 0.3 to 3 percent per hour. Again, this range represents an upper limit of the conversion rate for the conditions experienced on these two days.

Improvements in the method of SO_4 collection are now being investigated with the intent of increasing or concentrating the amount of sample which is collected. This would increase the resolution of the results and could lead to better definition of the conversion process and the factors which influence it.

4. Conclusions on Airborne Plume Sampling

Although the plume sampling performed during this program was exploratory in nature, the results were quite interesting and proved that an airborne sampling system is a valuable tool for studying plume structure and chemistry.

Both plumes sampled were virtually invisible yet were easily identified by their high NO_x, SO_2, and CN concentrations and by the deficit of ozone in the plume. The plume sampling pattern used for the Moss Landing work proved to be successful for mapping out the plume even though it was not easily visible by the crew.

Some of the other conclusions are listed below:

1. The NO to NO_2 conversion rate in a power plant plume is a highly variable quantity with strong dependence upon the constituents of the background air into which the plume is emitted. The conversion rate for the Ormond Beach plume with a high ozone background was about 80 percent in one-half hour.

2. The conversion rate of SO_2 to sulfate in the Moss Landing plume during the conditions studied was crudely determined to be between 0.3 and 3 percent per hour. This estimate is in rough agreement with estimates made by others in clean areas.

3. The plume height, dispersion rates, and concentrations were found to be highly dependent upon meteorological conditions in agreement with numerous previous dispersion studies. The NO_x concentrations in all the studies, however, were found to be between about 0.2 and 1 ppm at one mile from the plant. The initial stack concentrations for all the studies were about 200 ppm, indicating a dilution factor of 200 to 1000 within one mile.

4. There is evidence in the Ormond Beach data that emissions from point sources can contribute to high concentrations of pollutants in layers aloft near the coast and that these emissions may eventually react photochemically to form high levels of oxidant. This is important in that these layers aloft can impinge upon elevated terrain or can be ventilated to the surface if transported inland to an area of better mixing.

B. Spatial Distribution of Pollutants in the Upland Area - Possible Effect of Roadways

On October 4, 1972, a series of horizontal traverses were flown by the aircraft in the area between La Verne and San Bernardino. The purpose of the flights was primarily to examine the spatial structure of the pollutant fields in the vicinity of Upland where anomalously high ozone observations are frequently recorded. Orthogonal horizontal flights were made along the flight tracks as shown in Fig. IX-15. These tracks started with a short north-south flight along Euclid Avenue in Upland from the San Antonio Dam to the San Bernardino Freeway. A longer east-west flight was then made along Foothill Boulevard from the vicinity of Brackett Field (near Claremont) eastward to the western edge of San Bernardino. Flights were made along these tracks at 2500, 3500, and 4500 ft msl at about 1000 PDT and about 1600 PDT.

October 4, 1972, was a typical fall pollution day with easterly winds in the eastern portion of the Los Angeles Basin until about 1000 PDT. Characteristically high oxident values occurred in the east San Gabriel Valley after 1200 PDT. Figures IX-16 and IX-17 show soundings made at Fontana (about 10 miles east of Upland) at 1102 and 1657 PDT in air representative of that sampled during the horizontal traverses. Figure IX-16 shows relatively clean air in the morning with low O_3 and b_{scat} values even in the lowest layers. The mixing layer depth at that time was approximately 2800 ft msl as indicated primarily by the decreases in turbulence and condensation nuclei values at about that level. By late afternoon, there had been a considerable increase in O_3 and b_{scat} values in the low layers to a height of about 2700 ft msl. Peak O_3 values in this layer were slightly over 0.3 ppm. A peak ground level O_3 value of 0.36 ppm occurred at Upland during the hour beginning at 1600 PDT. Pibal wind observations were made at Upland in support of the aircraft flights. Wind directions and speeds at 1010 PDT and 1600 PDT are given in Table IX-3.

TABLE IX-3

PIBAL WIND OBSERVATIONS - UPLAND

Time	Height	Direction	Speed
1010 PDT	2000 ft msl	258°	5.6 mph
	2700	026	3.5
	3300	035	9.6
	3900	037	13.8
1600 PDT	2000	251	10.9
	2700	256	4.2
	3300	332	1.3
	3900	030	4.3

other peaks. The response time of all other instruments were much more adequate but still resulted in slight differences in peak position.

Since the plume was emitted into a layer with very high O_3 concentrations (approximately 0.4 ppm), a rapid rate of oxidation of NO to NO_2 would be expected. This was checked in a crude manner by comparing the NO_x/NO ratio at the 0.9 mile distance with that at the 2.7 mile distance. Since NO and NO_x were measured on different passes at each location, the peak values were normalized to the peak SO_2 concentration on each pass. This assumes that SO_2 is oxidized much slower than NO and is thus relatively conservative and that the SO_2 data are good enough for this purpose. The results are shown in Table IX-1. At 0.9 miles, the normalized NO reading is actually slightly higher than NO_x, and the actual peak NO and NO_x values are equal, indicating almost no conversion at this location. At the 2.7 mile point, both the ratio of the peak values and the normalized ratios indicate that about 80 percent or more of the NO has been converted to NO_x. At a wind speed somewhere between 3 and 7 mph, this conversion has taken place in 15 to 35 minutes. An indicator of consistency in the data is the fact that the NO_x/SO_2 ratios at both distances are roughly equal, indicating comparable dilution of both species.

The data and sampling procedures for Ormond Beach were quite crude, but much useful information was obtained. By the time of the sampling at Moss Landing, the procedures were more refined, and better data on the plume structure were obtained.

TABLE IX-1

CONVERSION OF NO TO NO_x IN ORMOND BEACH PLUME

Pass #	Distance (miles)	NO or NO_x	NO(x) Peak Value (ppm)	Peak SO_2 (ppm)	$\frac{NO(x)}{SO_2}$	$\frac{NO_x}{NO}$	Normalized NO_x/NO
1	0.9	NO_x	1.04	0.30	3.5	1.0	0.74
2	0.9	NO	1.04	0.22	4.7		
3	2.7	NO	0.10	0.1-0.14	0.7-1.0	5.6	3.7-5.3
4	2.7	NO_x	0.56	0.15	3.7		

3. Moss Landing Power Plant

a. Introduction and Procedures

The Moss Landing Power Plant was chosen for study because of ARB interest in obtaining data for that plant and because it presented a situation which contrasted with that at Ormond Beach. The plant is located on the central California coast about 12 miles north of Salinas. It has seven operating units with a total capacity of roughly 1500 megawatts; however, Units 6 and 7 generally account for about 90 percent of the plant's output. These two units have an output of about 500 megawatts each. During the sampling period, the plant was burning oil.

The plume was sampled in cool overcast winter weather during conditions varying from slightly stable to unstable. The plume was emitted into clean air with approximately background level ozone concentrations (0.04 ppm). Three sampling flights were made on 9 and 10 January 1974 and will be discussed here. Surface streamlines and meteorological data for those days can be found in the 1973 data volume. The plume characteristics for each flight are discussed first, then analyses of the conversion rates of NO to NO_x and SO_2 to sulfate in the plume are presented.

Salinas airport was used as a base of operations for all the sampling flights. The normal procedure after takeoff was to obtain a vertical profile above the airport in order to document background gaseous and particulate concentrations and meteorological parameters, particularly the temperature structure.

The Moss Landing stacks were then circled to locate the plume by instrument response. Once the direction of the plume was established, traverse paths crossing the plume at various downwind distances were selected. A typical sampling pattern is shown in Fig. IX-4. The first sampling was done along the traverse path nearest the plant, flying along this route repeatedly at a series of different altitudes. The lowest altitude was below the plume, if possible, or as low as safety would permit. Sampling altitudes were successively increased until one or two traverses were made above the plume. This procedure was then repeated along each traverse path. An additional vertical sounding through or near the plume was made at the end of each flight.

Data from each plume sampling flight were reduced, and the relevant meteorological and pollutant parameters were plotted as a function of time (equivalent to distance) for each traverse. Cross-sections and contour maps of the plume were developed from these data. Although numerous parameters were measured, only NO_x, and sometimes SO_2, concentrations were used in the contour maps since they are considered to be

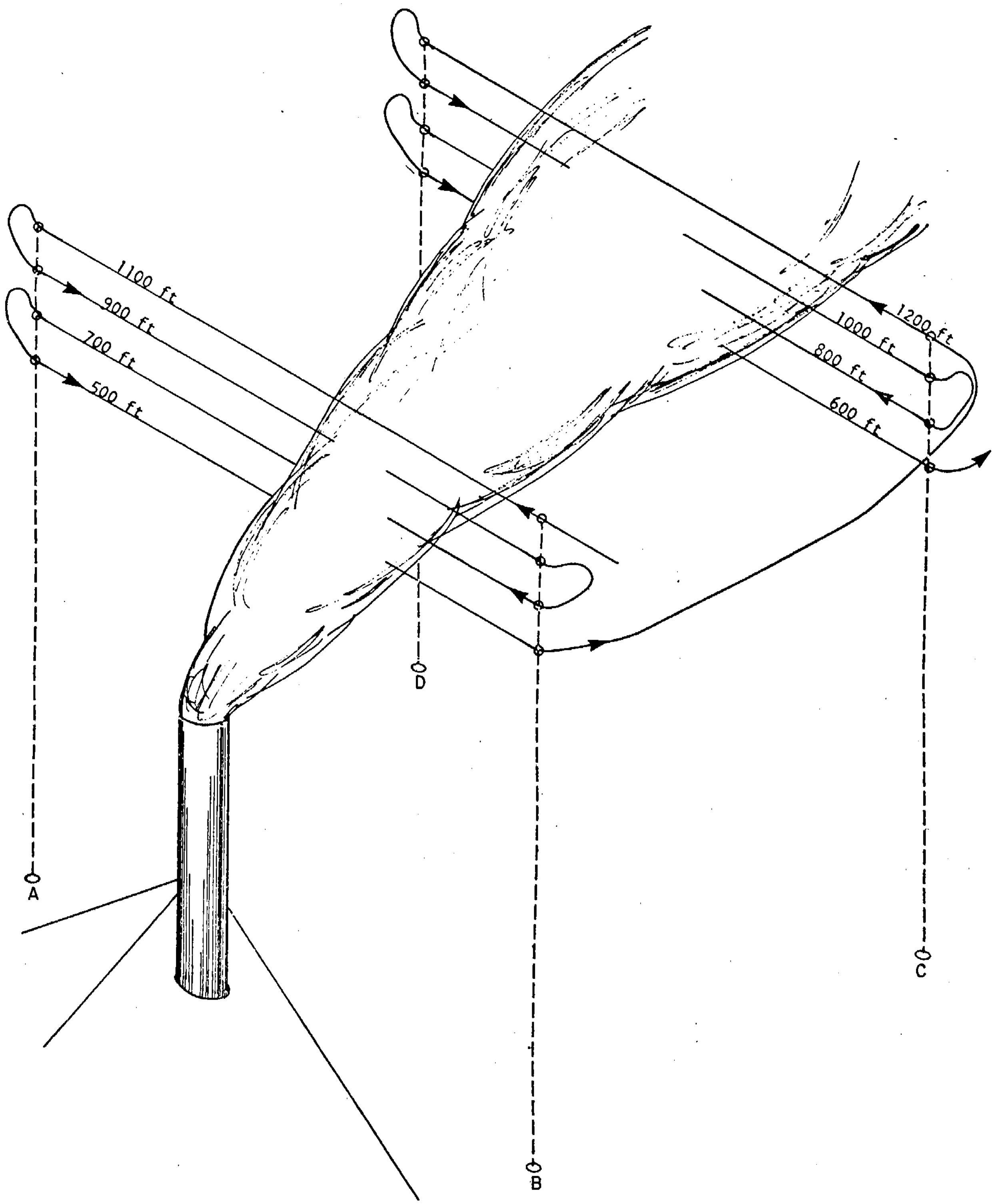


Fig. IX-4. PLUME SAMPLING FLIGHT PATTERN FOR INVISIBLE PLUMES. POINTS A, B, C, AND D ARE GROUND REFERENCE POINTS WHICH SHOULD BE LAYED OUT BEFORE FLIGHT.

the best plume indicators. In addition to the aircraft data, some wind and plant operational data were obtained from Pacific Gas and Electric Company, operators of the plant.

One of the problems encountered in the aircraft monitoring of stack plumes is that most instruments do not respond rapidly enough to short pulses of pollutants to accurately measure their concentrations near the source. The errors involved can be large. MRI has recently performed a study of instrument response characteristics and has developed a mathematical technique for correcting for transient response. Application of this program to plume data corrects the recorded data to the actual plume concentrations. Since this correction has not been applied to the data in this report, it should be kept in mind that the concentrations reported may be significantly lower than the true concentrations for the narrow portions of the plume close to the source.

All times mentioned in this section are PDT, and altitudes are relative to mean sea level (msl) unless otherwise noted. Ground elevation at the Moss Landing plant is approximately 20 feet, and the stacks are 500 feet high.

b. January 9, 1974 - Afternoon Sampling

(1) Meteorology

General overcast conditions prevailed in the Monterey-Salinas area throughout the day; the base of the stratus deck was estimated to be at about 3500 feet (msl) above Moss Landing at the time of the afternoon flight. At mid-afternoon, a westerly sea breeze had penetrated most of the area, but by evening, it remained only in the northern half of the Salinas Valley. Surface temperatures throughout the afternoon were in the low 50's, and visibilities ranged from 15 to 20 miles.

(2) Plume Characteristics

Aircraft sampling began at 1540 PDT with a sounding above the Salinas Airport showing a neutral lapse rate to at least 2800 feet. Surface winds at Moss Landing were from the west at about 4 mph, although the plume location indicated a more southwesterly flow at plume altitudes. The approximate plume location and the traverse paths for this flight are shown in Fig. IX-5. The first series of traverses was made 1/2 mile downwind where the plume was mapped by a number of traverses between 1000 and 3000 feet (msl). Plume sampling 2-1/2 miles downwind consisted of five traverses in the same altitude range. During and prior to the sampling period, units 6 and 7 were each operating at about 250 megawatts and in-stack measurements indicated about 210 ppm of NO_x in the exhaust of each stack.

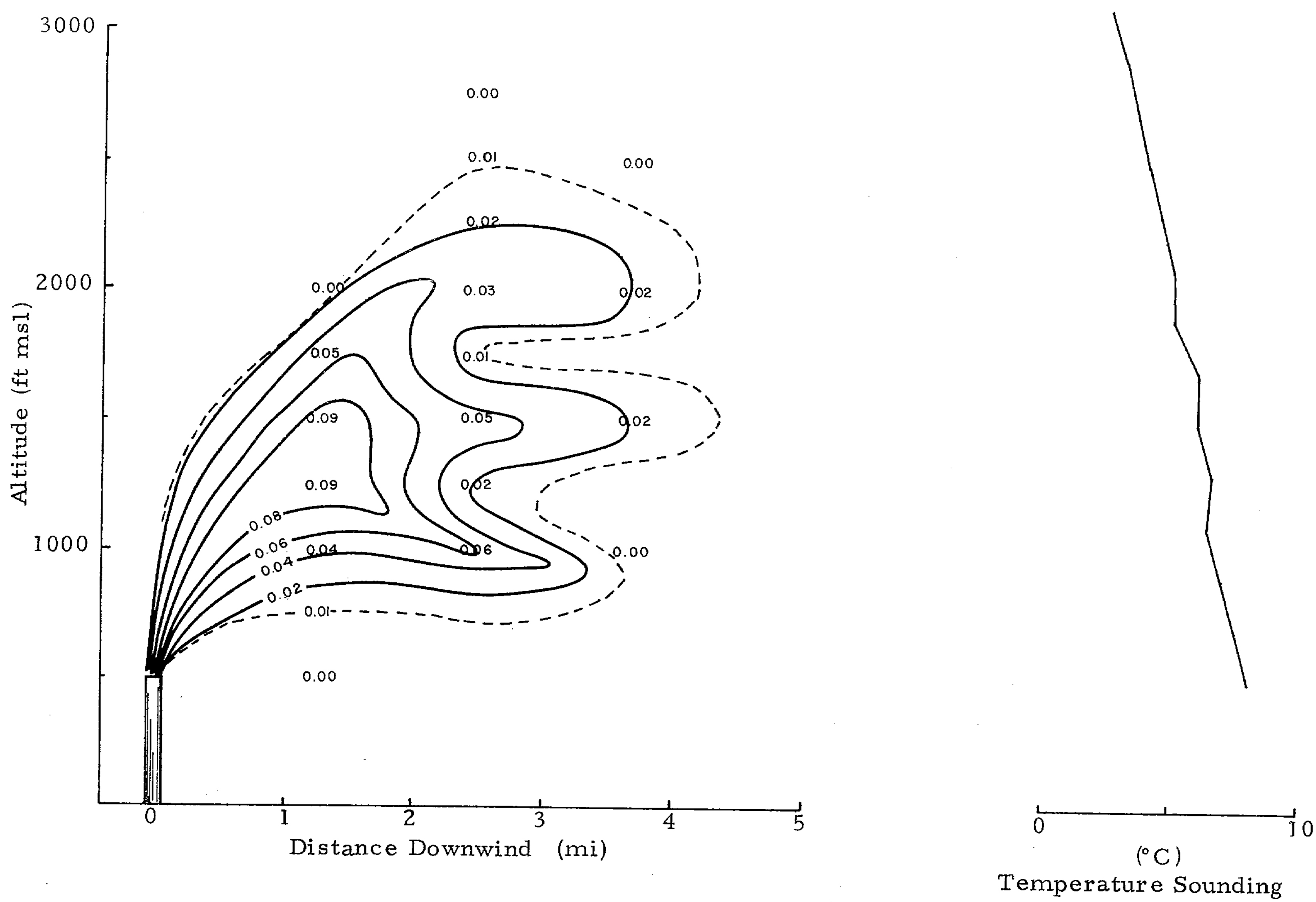


Fig. IX-14. MOSS LANDING PLUME PROFILE SHOWING MAXIMUM TRAVERSE SO_2 CONCENTRATIONS (ppm), 1355-1545 PDT, JANUARY 10, 1974

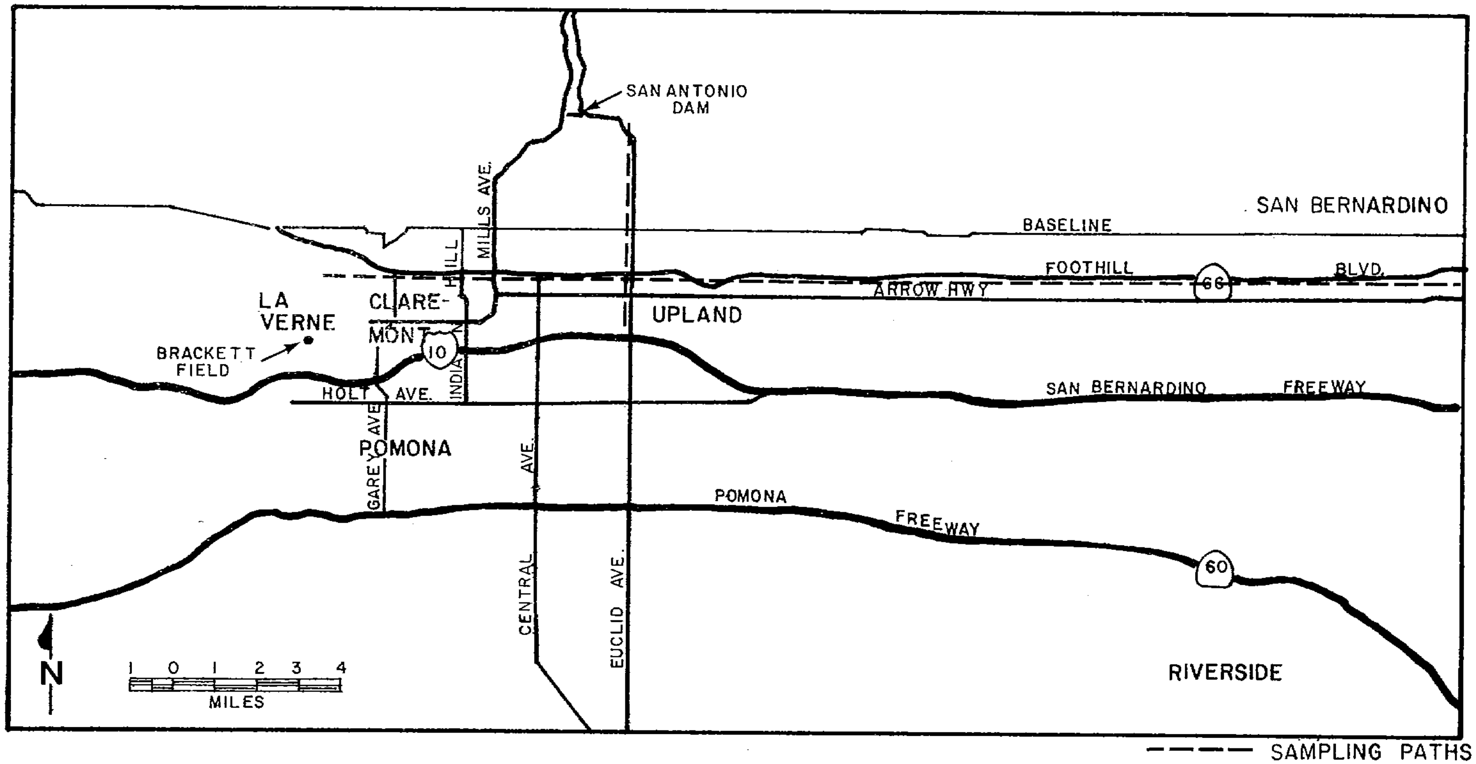


Fig. IX-15. SAMPLING PATHS FOR HORIZONTAL FLIGHTS IN UPLAND AREA, OCTOBER 4, 1973

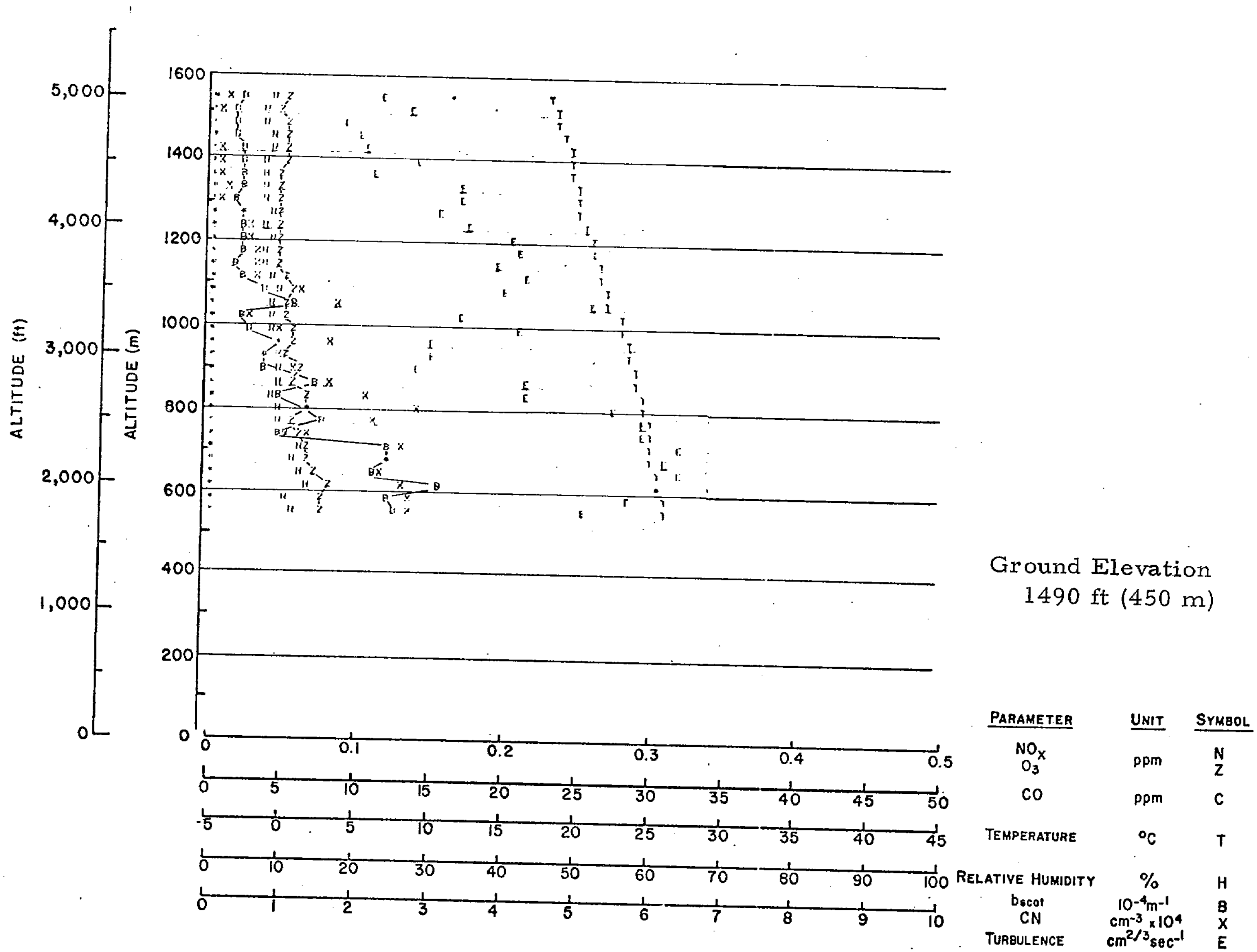


Fig. IX-16. VERTICAL PROFILE OVER FONTANA 1102 PDT, OCTOBER 4, 1973

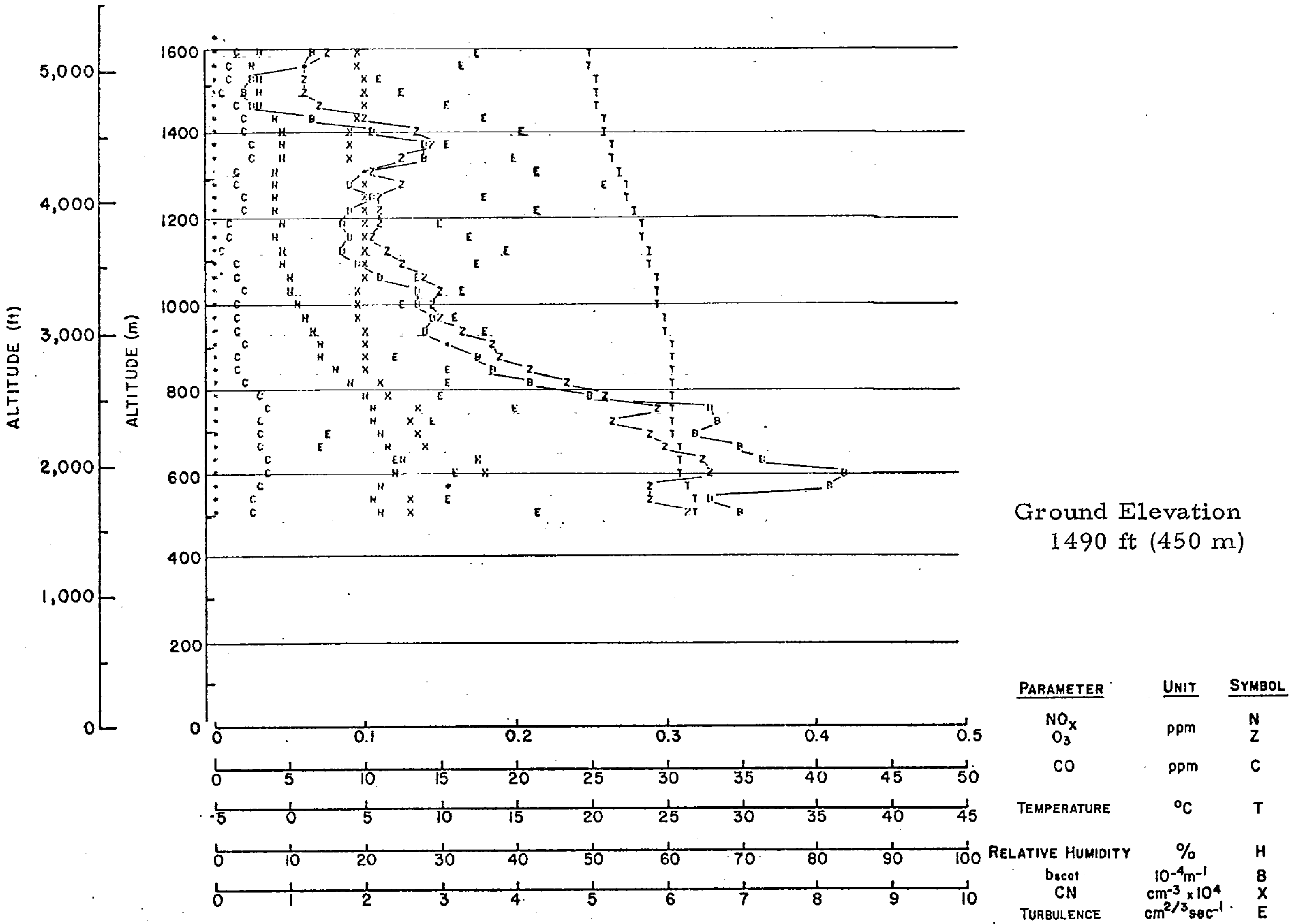


Fig. IX-17. VERTICAL PROFILE OVER FONTANA 1658 PDT, OCTOBER 4, 1973

These observations indicate a strong directional wind shear at about the 2700-ft (msl) level which represents the top of the mixing layer in reasonable agreement with the aircraft soundings.

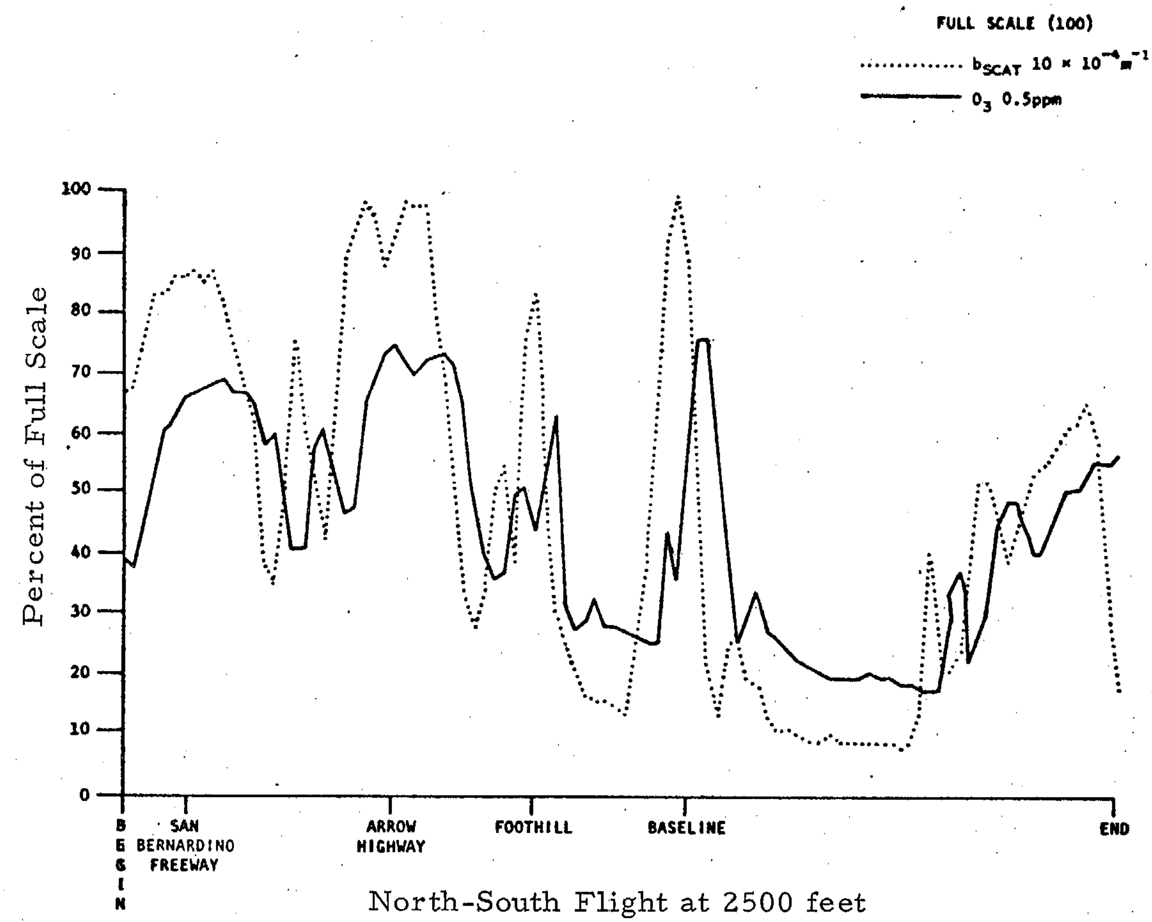
Figure IX-18 shows the records obtained for b_{scat}, O_3, CN, and NO_x along the five-mile route from San Antonio Dam to the San Bernardino Freeway during the afternoon flight (2500 ft msl). Major variations in all of the pollutant parameters can be seen at flight level with a high degree of correlation between the various parameters. The small time lag between the O_3 and b_{scat} peaks is attributable to differences in instrument time response.

An examination of possible reasons for the large variations in pollutant levels shown in Fig. IX-18 turned up a possible correlation with major highways in the area. Locations of these road systems (perpendicular to the flight path) are shown in the figure. The principal area of influence appeared to be associated with the San Bernardino Freeway. At the other end of the flight path, the terrain is higher relative to the flight altitude so that the increases near San Antonio Dam may reflect general surface heating effects.

Traverses were made along the same flight path at 3500 ft msl and 4500 ft. These data have been used to construct the vertical O_3 cross-section shown in Fig. IX-19. Although considerable smoothing has been introduced due to the 1000-ft flight level differences, the pollutant peaks remain definable to 4500 ft msl although in a considerably damped manner.

Figure IX-20 shows a portion of the traces observed on an east-west traverse along Foothill Boulevard. The data were obtained during the afternoon flight at a level of 2500 ft msl. Although considerable fluctuations are evident in the data, the peaks are not as pronounced as in the north-south traverse. There are indications, however, that Indian Hill, Mills, and Euclid Avenues may have significant correlations with the pollutant levels at flight altitude. It should be remembered that the wind (Table IX-3) was nearly parallel to the east-west highways but perpendicular to the north-south streets. Pollutant variations due to the highways would consequently be more pronounced on north-south flight traverses.

Figure IX-21 shows the results of a morning flight on a north-south route similar to Fig. IX-18. In this case, the principal pollutant characteristic is a large increase in condensation nuclei near the San Bernardino Freeway. In view of the relatively clean background air



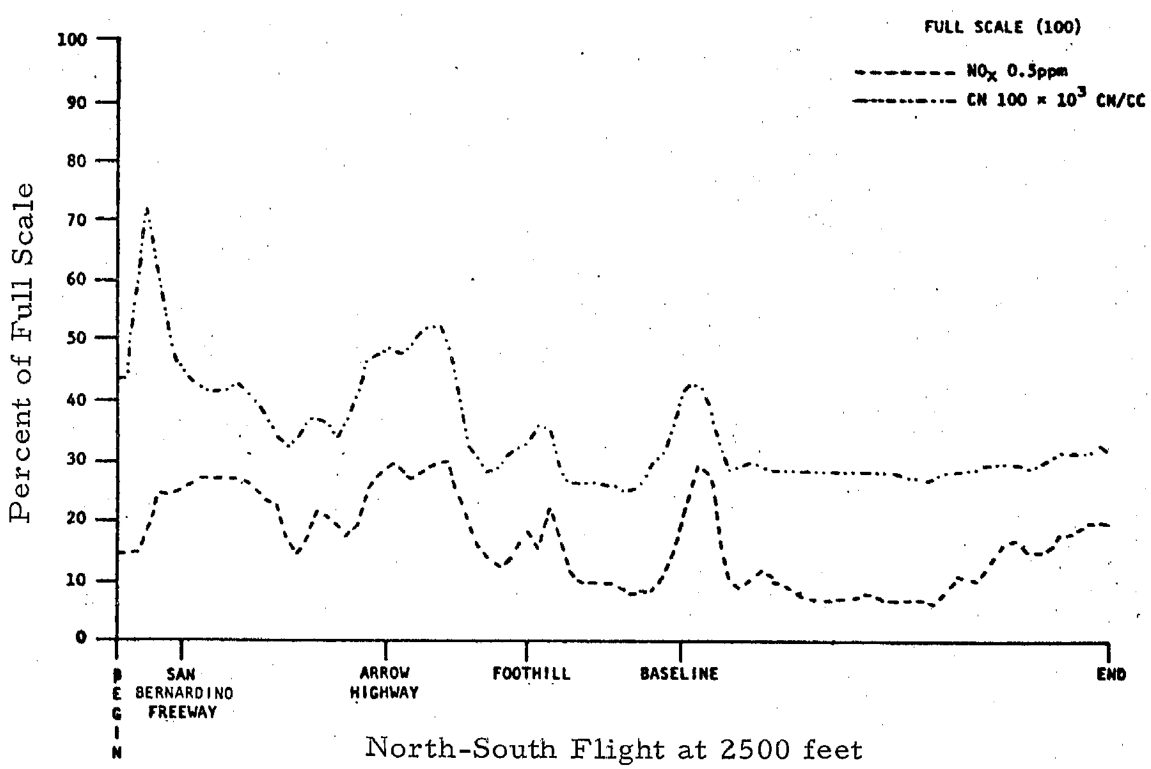


Fig. IX-18. NORTH-SOUTH TRAVERSE ALONG EUCLID AVENUE, UPLAND, FROM SAN BERNARDINO FREEWAY TO SAN ANTONIO DAM, AFTERNOON FLIGHT

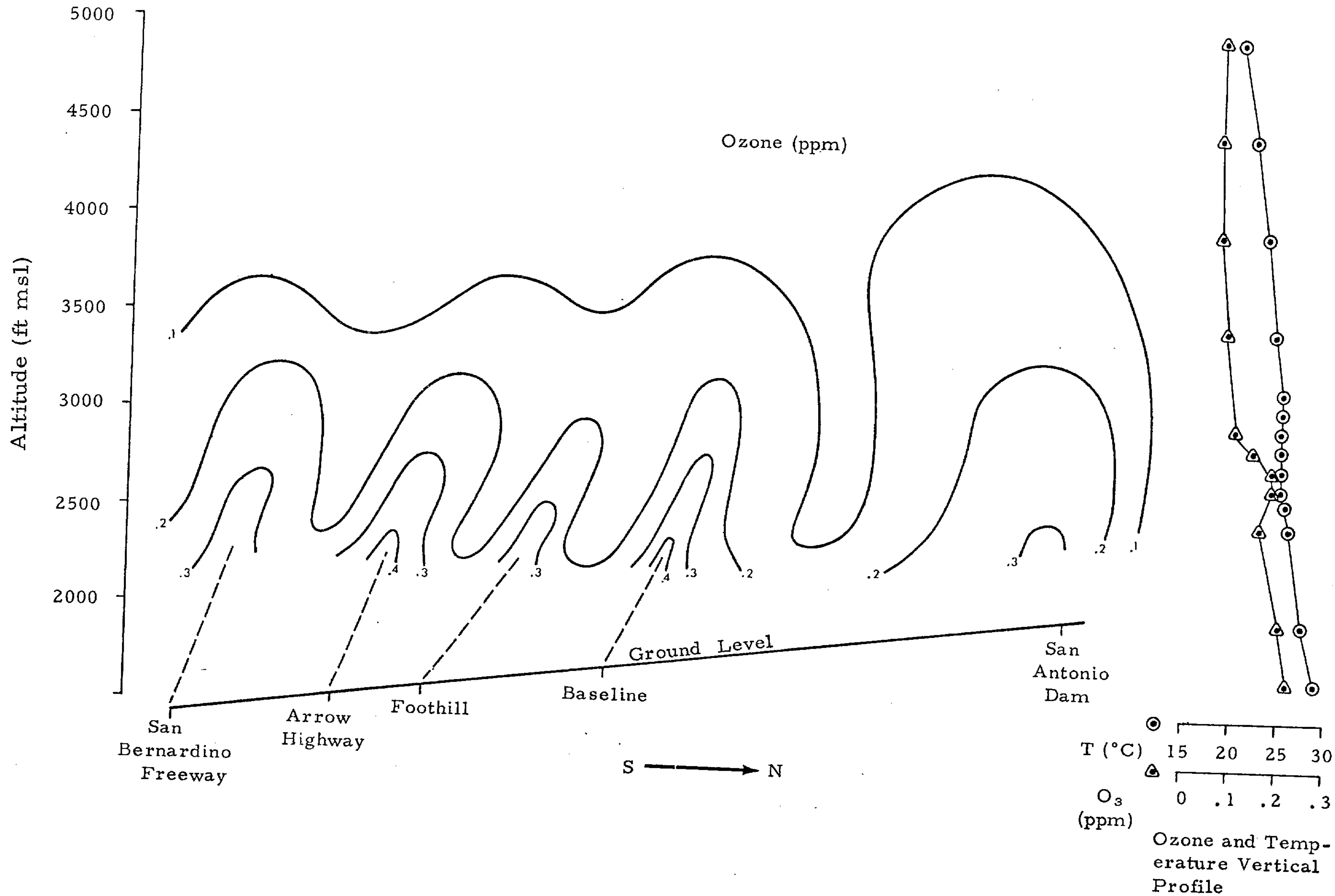
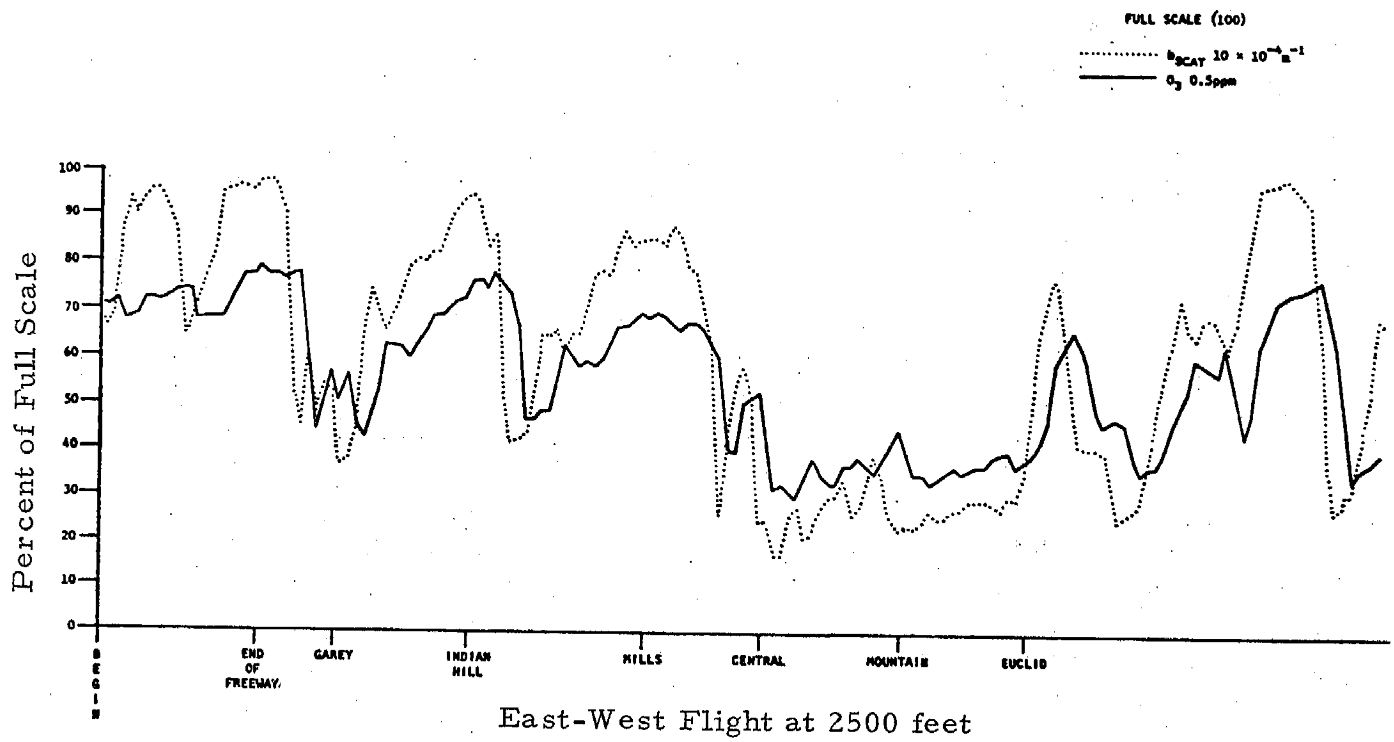


Fig. IX-19. VERTICAL CROSS-SECTION OF OZONE CONCENTRATIONS ALONG EUCLID AVE., UPLAND, OCTOBER 4, 1973, AFTERNOON



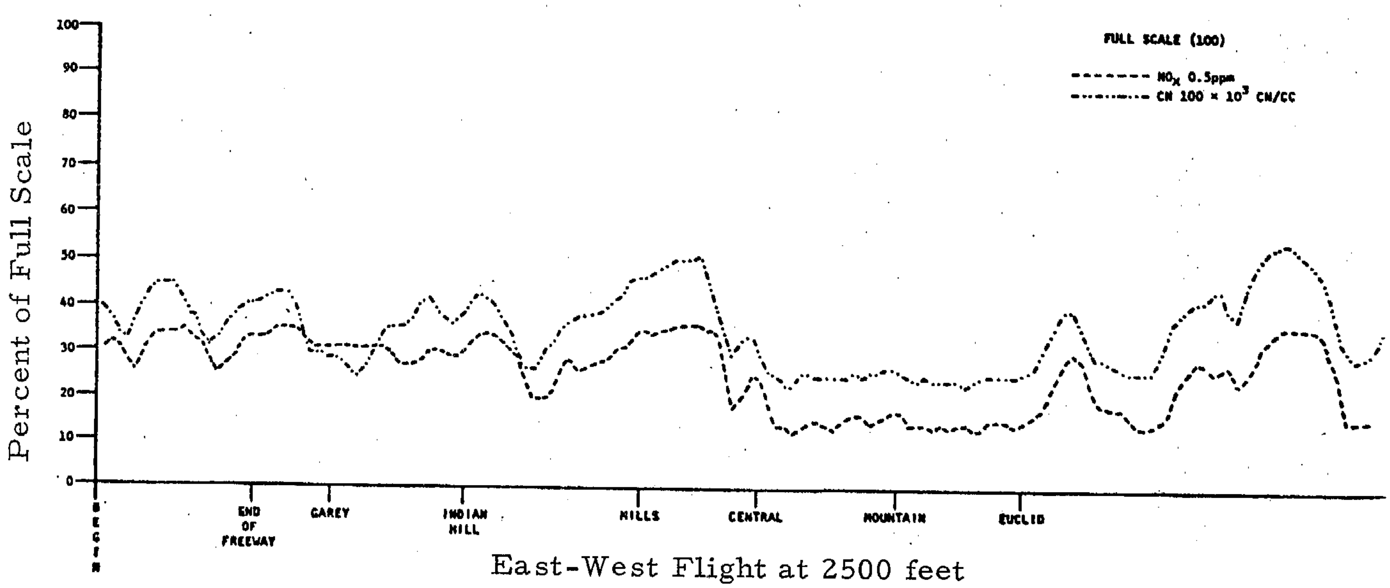
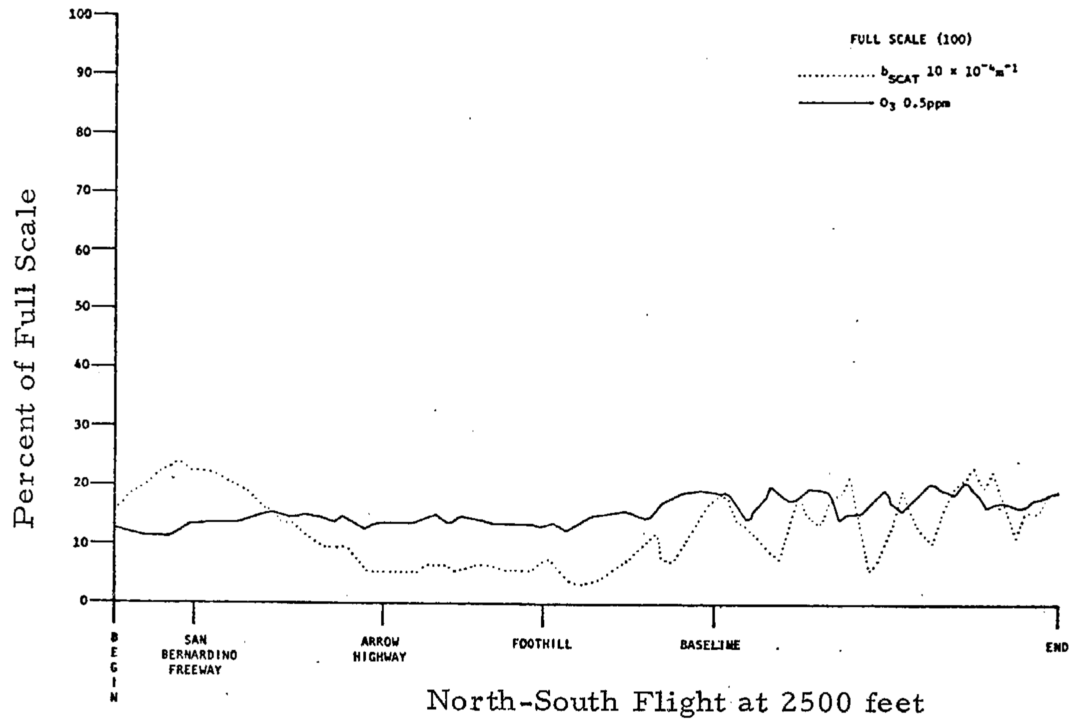


Fig. IX-20. EAST-WEST TRAVERSE ALONG FOOTHILL BLVD. FROM LA VERNE TO SAN BERNARDINO AT 2500 FEET, AFTERNOON FLIGHT



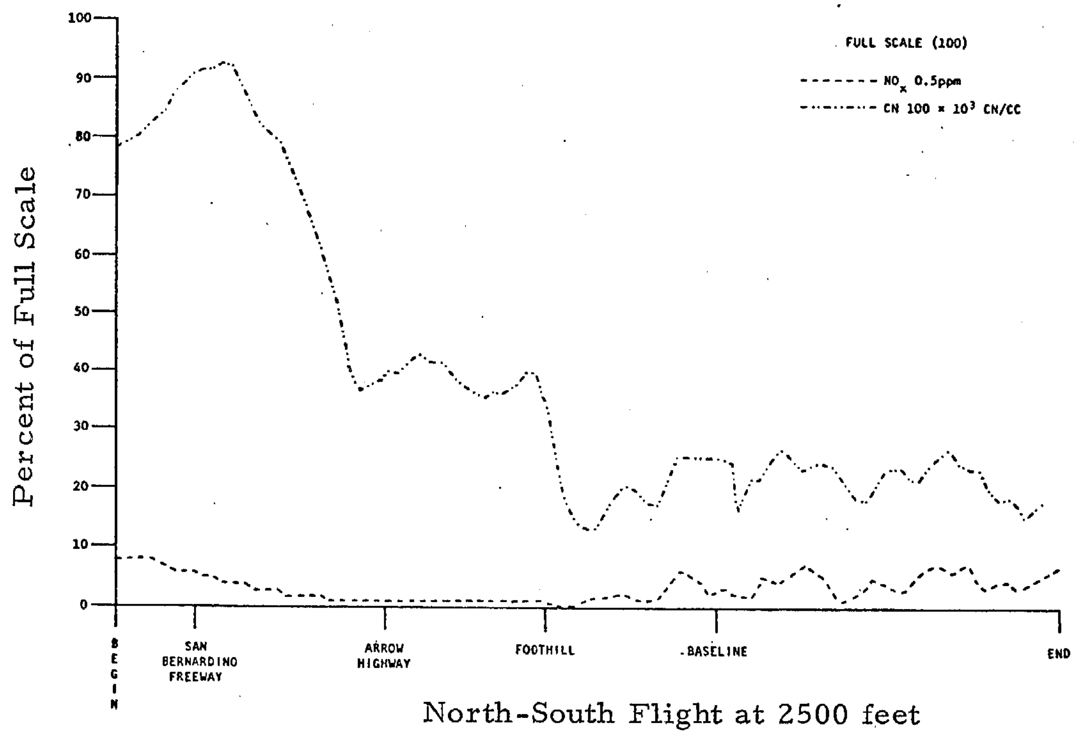


Fig. IX-21. HORIZONTAL TRAVERSE ALONG EUCLID AVE., UPLAND, FROM SAN BERNARDINO FREEWAY TO SAN ANTONIO DAM, MORNING FLIGHT AT 2500 FEET during the morning flight (Fig. IX-16), condensation nuclei would be expected to be a major pollutant parameter close to the freeway.

Both morning and afternoon flights at 2500 ft msl were made near the top of the mixing layer where vertical gradients in pollution parameters are relatively large. Thus, upward displacements of surface air parcels to the top of the mixing layer could easily explain the occurrence of such large variations as were observed. In addition, the existence of such effects at flight levels somewhat above the normal mixing layer top (Fig. IX-19) argues in favor of upward displaced air parcels of a buoyant nature. Peak pollutant values observed near the top of the mixing layer were about the same as those characteristic of the surface conditions. It is therefore considered likely that the major variations occurred during traverses such as Fig. IX-18 result from buoyant line sources associated with the principal highways in the area. The highway traffic pollution undoubtedly contributes to these peaks, but most of the pollution observed at flight level appears to result from the displacement of surface air upward. Although it is beyond the scope of this study, it is reasonable to expect that the main source of the buoyant air is the heating of the roadway surface rather than the heat energy introduced by the cars themselves.

C. Aerosol Sampling for Electron Microscopy

The two aerosol parameters monitored continuously during the three-dimensional pollutant gradient study were the light-scattering coefficient and condensation nuclei count. These observations were complemented by selective sampling of aerosol for direct observation with a transmission electron microscope. Aerosol was collected by a five-stage round jet inertial impactor with nominal cutoff diameters of 0.25 (stage 5), 0.5 (4), 2.0 (3), 4.0 (2), and 8.0 (1) microns, and studied under the transmission electron microscope at W. M. Keck Laboratories, CalTech. Figures IX-22a, b, c, and d show typical electron micrographs of samples on stages 4 and 5, which collect most of the light-scattering particles (Fig. V-25).

For reference, Fig. IX-22a shows aerosol collected on impactor stage 4 near ground level in Pasadena. The electron micrograph shows both solid particles (with white shadows) and liquid droplet residues (with practically no shadow).

Figures IX-22b and c show aerosol collected on impactor stage 5 in an elevated pollutant layer at 2100 ft msl over Pasadena. The electron micrographs show two areas of the same electron microscope grid, Fig. IX-22b being closer to the impaction jet centerline than IX-22c. Contrasts between these elevated samples, which represent predominantly aged aerosol, and the ground level sample of Fig. IX-22a, which represents a mixture of fresh and aged aerosol, are apparent.

Nearly all of the particles appearing in Fig IX-22b and c are liquid droplets. Without exception, each of the droplet residues contains a nucleus of high electron opacity. These nuclei, most of which have diameters of about 0.02 microns and resemble poppy seeds in the electron micrographs, are similar in appearance to particles present in large numbers in automobile exhaust. The above observations strongly suggest that the aerosol at 2100 ft grew by heterogeneous nucleation on solid primary aerosol particles. It has previously been hypothesized (e.g., Husar and Whitby, 1973) that this is the primary mechanism of photochemical aerosol production in the Los Angeles Basin.

Many of the larger droplet residues in Fig. IX- 22b and c contain numerous nuclei. This is due in part to superposition of droplets on the impactor stage. It appears also to be due in part to coagulation in the atmosphere of droplets with both other droplets and with primary nuclei.

In Fig. IX-22d, a droplet residue from impactor stage 4, which was collected at the same time as the samples shown in Figs. IX-22b and c, is magnified to the point where the structure of its nucleus can be seen. The opaque nucleus has a cubical shape and a diameter of about 0.07 micron. The cubical shape suggests that the nucleus is a salt crystal.

X. ACKNOWLEDGMENTS

This program and report were obviously the work of many people, and the authors would like to thank them all and acknowledge their contributions.

First, we would like to thank the California Air Resources Board for their support and funding of this project, and especially the late Dr. Dale Hutchinson, Mr. Harris Samuels, and Dr. Jack Suder of the ARB for their cooperation and flexibility in administering the program.

The field program and much of the preliminary data reduction were completed with much help from our co-investigators, the U. S. Naval Weapons Center at China Lake, California, under the direction of Mr. Paul Owens. Mr. Owens was responsible for instrumenting, maintaining, and running the Navy van and aircraft. He coordinated the Navy's effort with MRI and, on many occasions, ran the complete field program. Mr. Owens was aided in his efforts by Mr. Ray Kelso and Ms. Peggy Davis of China Lake who acted as observers during the flights and helped operate and maintain the instrumentation. In addition, he was supported by the Naval Weapons Center's staff of pilots, directed by Lt. David Debenport who often flew the Navy aircraft.

The MRI effort could not have been accomplished without the help of many other MRI participants. Mr. Stuart Muller instrumented and maintained the aircraft and acted as observer on most of the flights. Ms. Anne Ostrye and Ms. Kris Lamb were responsible for much of the data processing and data reduction. Mr. Al Ollivares generally flew the MRI aircraft and was responsible for its maintenance; and Mr. Travis Howland and Mr. Stan Howard were responsible for most of the meteorological forecasting and data collection for the program. Numerous other MRI employees were also involved in this program and their help is greatly appreciated.

A special note of thanks is due Mr. Paul Le Vier who assisted in setting up the computer data processing system and who wrote almost all the software included in the program. We would also like to thank Foothill Aircraft Service who provided us with a base of operations and who kept the MRI aircraft maintained and ready to go on a moment's notice. In addition, we appreciate the efforts of Metronics, Inc., for their cooperation in supplying pibal and tracer data and Mr. P. Roberts of Caltech for his sulfate filter analysis.

And last, but by no means least, heartfelt thanks to MRI Publications Department and Ms. Jacque Foreman.

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Appendix A

AIRCRAFT AND VAN INSTRUMENTATION

A. Discussion of Instruments

This section discusses in detail the instruments chosen to monitor pollutants in this study. The aerosol sensors selected were the MRI Integrating Nephelometer and the Environment One Condensation Nuclei Monitor. These instruments were found to be the aerosol samplers best suited to the aircraft environment which requires ruggedness and fast time response. The integrating nephelometer described by Ahlquist and Charlson (1968) measures the scattering coefficient of the ambient air by detecting the light scattered from an illuminated air sample. The scattering coefficient is inversely proportional to the meteorological range and proportional to the mass concentration of the aerosol. The scattering coefficient is primarily due to particles in the 0.1 to 1.0 micron diameter size range.

The condensation nuclei monitor described by Rich (1970) is sensitive to particles less than 0.1 micron in diameter. The instrument humidifies an air sample and expands it in a cloud chamber, causing condensation on the particles in this size range. The resulting cloud attenuates a light beam which is focused on a light-sensitive element. Use of both the condensation nuclei monitor and the integrating nephelometer thus allow measurements of particle concentrations in two important size ranges.

The gaseous monitors measured carbon monoxide, NO or NO_x, and ozone. The Andros CO monitor uses the dual isotope fluorescent source nondispersive infrared absorption technique described by Link et al (1971); the principal advantage of this technique is the lack of sensitivity to vibration. The Bendix CO monitor in the van uses the usual nondispersive infrared absorption technique.

The REM O_3 and NO-NO_x monitors are both chemiluminescent devices. The ozone monitor detects the reaction of ozone with ethylene. The NO-NO_x monitor observes the reaction between NO and internally generated ozone; NO_x can be measured by first passing the sample through a catalytic converter which reduces NO_2 to NO.

Prior to the 1973 sampling program, a number of modifications were made to the REM NO-NO_x and the Andros CO monitors. These included the replacement of the stainless steel converters in the NO-NO_x

monitors with molybdenum ones and the modification of the sample chamber to operate under a partial vacuum instead of at atmospheric pressure. This resulted in an increase in the lifetime and specificity of the converter, and increased sensitivity and zero stability. Data obtained using this modified equipment were superior to that obtained during the 1972 program. Modifications to the CO monitor consisted of the installation of zero filters (hopcalite) in both aircraft to allow periodic checks during flights.

The meteorological parameters of temperature, relative humidity, and turbulence were monitored with an MRI Airborne Instrument Package. The ambient temperature outside the aircraft is measured by a vortex temperature sensor using a thermistor for the sensor. The relative humidity sensor uses a strain gauge to measure the stress on a cellulose fiber, the accuracy of the measurement being about ±5% RH. Turbulence is measured by an MRI Universal Indicated Turbulence System described by MacCready et al (1965). The sensor is a standard pitot-static probe connected to a Validyne P-24, 0.7 psi D differential pressure transducer. The instrument measures pressure fluctuations in the 2 to 40 Hz range and the signal is processed to give an output proportional to the energy dissipation rate to the 1/3 power. The scale of 0 to 10 $cm^{2/3}$ sec^{-1} spans a range from calm air to what is considered severe turbulence for a light plane. The output of the instrument is independent of the type and speed of the aircraft.

B. Description of Aircraft Sampling System

Figure A-1 shows the arrangement of the instruments in the Cessna 205 aircraft. The sample inlet tubes were installed in a dummy window panel on the right-hand side of the aircraft. There was no interference between the sample inlet and the engine exhaust located under the engine cowling. The effect of the propwash and slipstream on the sample was reported by Adams and Koppe (1969) to be unimportant.

Figure A-2 shows the sample flow piping in the same aircraft. The instruments exhaust into the cabin; the venturi exhaust, however, guarantees cross ventilation to remove any noxious gases emitted from the instruments. The cabin is also vented to the atmosphere through the tail of the plane to keep the cabin-atmosphere pressure difference to a minimum.

Ram pressure is used to move air through the large 1-3/4 inch inlet tubes during flight. Since there were very few flow restrictions, the velocity in the large sample tube was on the order of the airspeed of the aircraft. The gas monitors are connected to the inlet manifold by a short length of 1/4 inch O.D. teflon tubing. The residence time in the sample lines was less than one second for all instruments. Static ports in the manifold

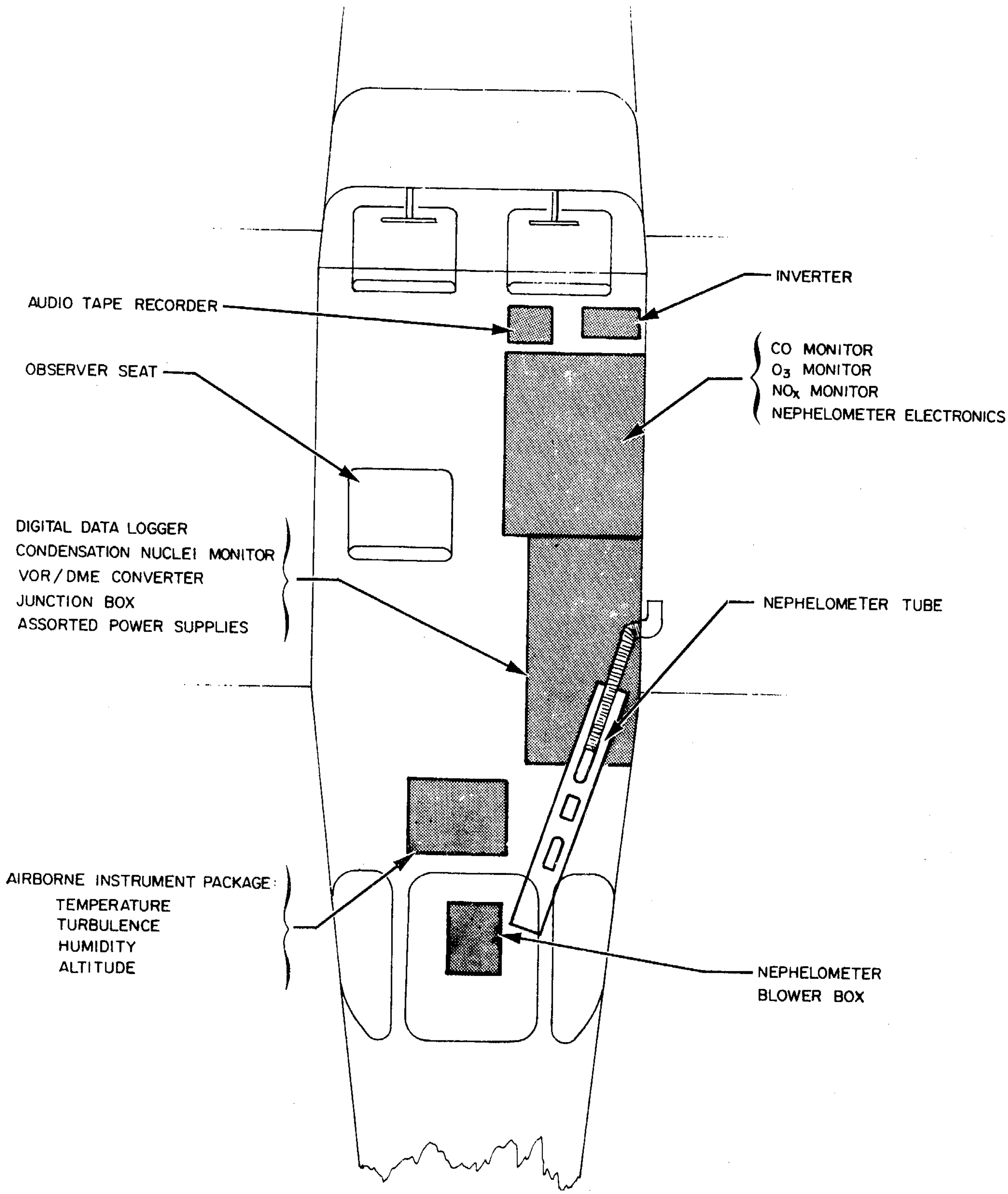

Fig. A-1. INSTRUMENTATION LAYOUT FOR CESSNA 205

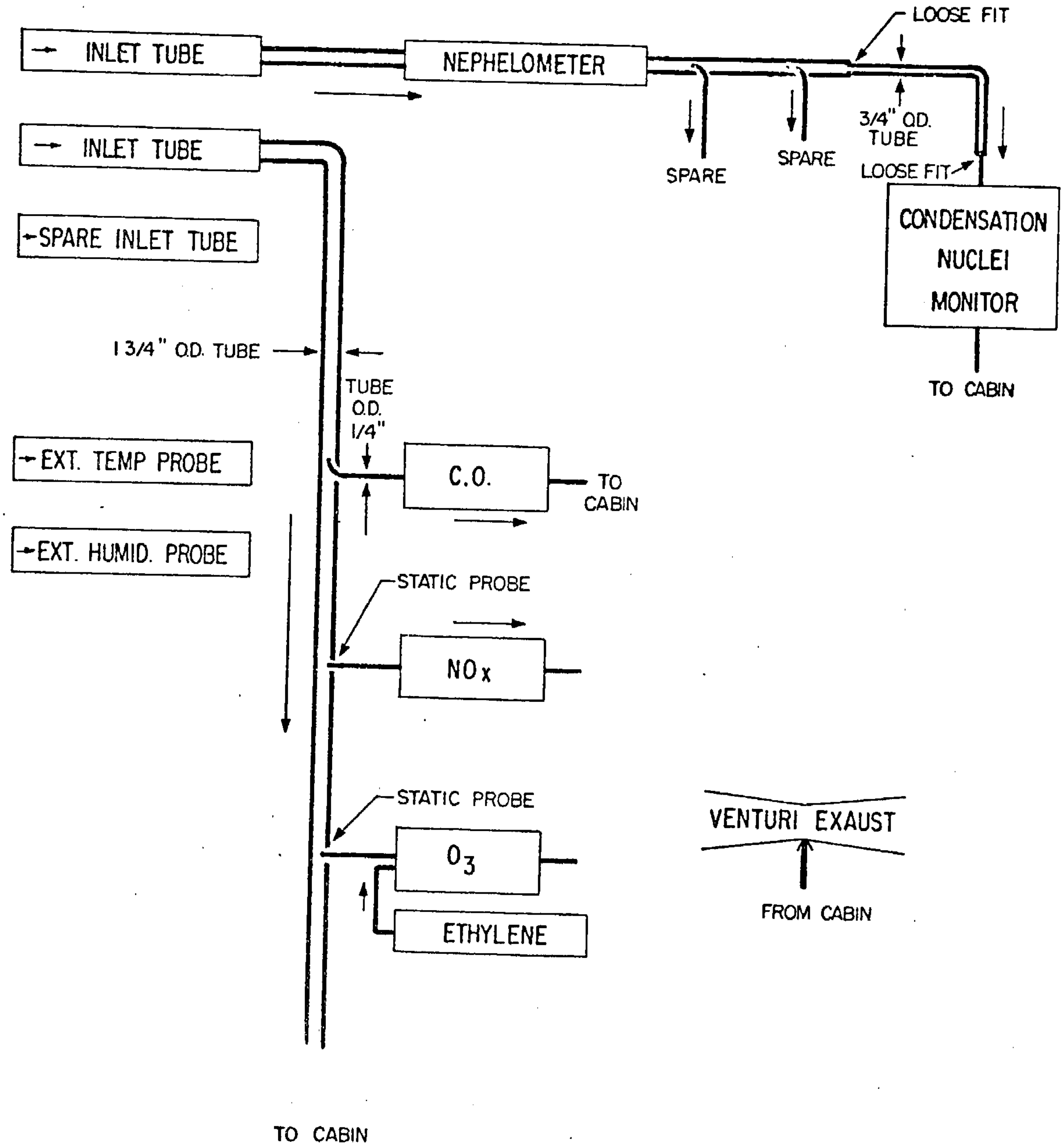

Fig. A-2. SAMPLE FLOW DIAGRAM IN CESSNA 205 were used for the flow-sensitive chemiluminescence ozone and NO_x monitors to prevent changes in flight speed from affecting the output of the instruments.

Figure A-3 is a schematic diagram of the instrument wiring system. The output of each instrument is directed through the junction box to the input of the data logger. All instruments are plugged into the junction box with banana plugs, thus permitting any necessary wiring changes. Instruments can be added to or removed from the data system with ease. The VOR, DME, and M/8 boxes in Fig. A-3 are part of the position recording system and are used to detect the radial and distance from a radio station. The tape code is used to label one of the channels on the tape as a backup identification system. The Mode/Event switch is used to mark events during the flight; ten different modes with ON/OFF positions are available.

The electrical output from each monitor is fed to a Metrodata 20-channel recorder where it is converted to a digital form and recorded at one-minute intervals. Data loggers with zero to 10-volt input ranges were used during the 1973 program eliminating overranging problems incurred during the 1972 program when five-volt data loggers were used.

The Cessna 310 was set up almost identically to the 205. The wiring and sample flow diagrams were essentially identical although the instruments were placed in different positions inside the aircraft due to differences in aircraft configuration.

Figure A-4 is a photograph of the Cessna 205 showing the sampling ports. Figure A-5 shows the inside of the 205. Figure A-6 is a photograph of the 310 and Fig. A-7 shows the instrument installation in the 310.

C. Description of Van Sampling System

The basic truck was a 1966 International Metro which was refurbished for this project. It was equipped with instrumentation similar to that in the aircraft, the main difference being the CO monitor and the meteorological sensors. The van instrumentation is listed in Table II-2 of the text. Other instruments were included in the van and are shown on the plumbing and wiring diagrams but were not used during this program. Monitoring equipment was installed in racks such that each monitor was guaranteed reasonable access for maintenance and was positioned as close as possible to the sample inlets. All monitors could easily be observed for proper operation. Sample inlets consisted of Type I PVC, two-inch I. D. pipe which penetrated the floor and roof of the van. A small fan exhausted the sample tube below while new sample air was drawn in from above. On

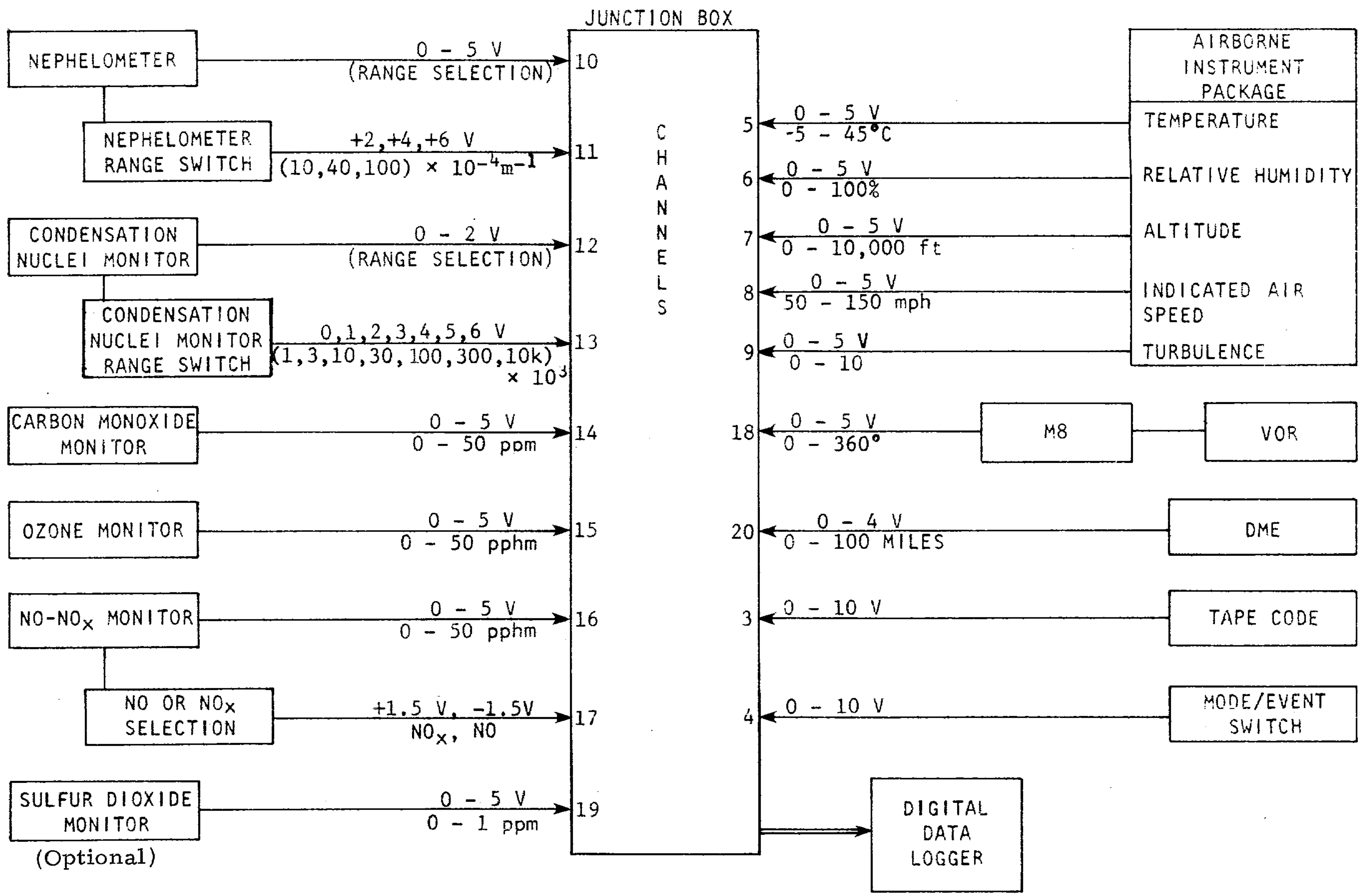

Fig. A-3. INSTRUMENTATION WIRING SCHEMATIC

Fig. A-4. CESSNA 205

Fig. A-5. INSIDE OF CESSNA 205

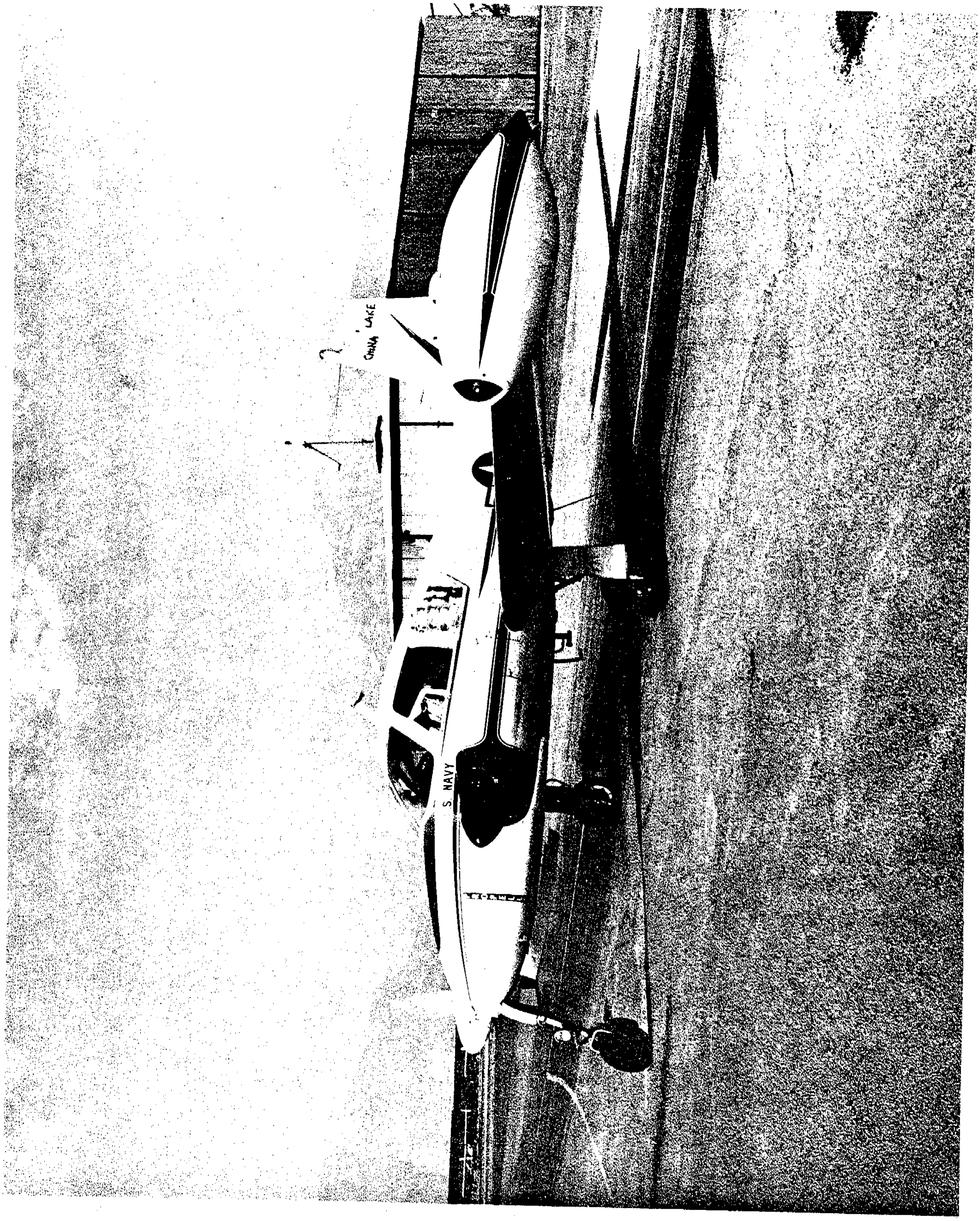

Fig. A-6. CESSNA 310

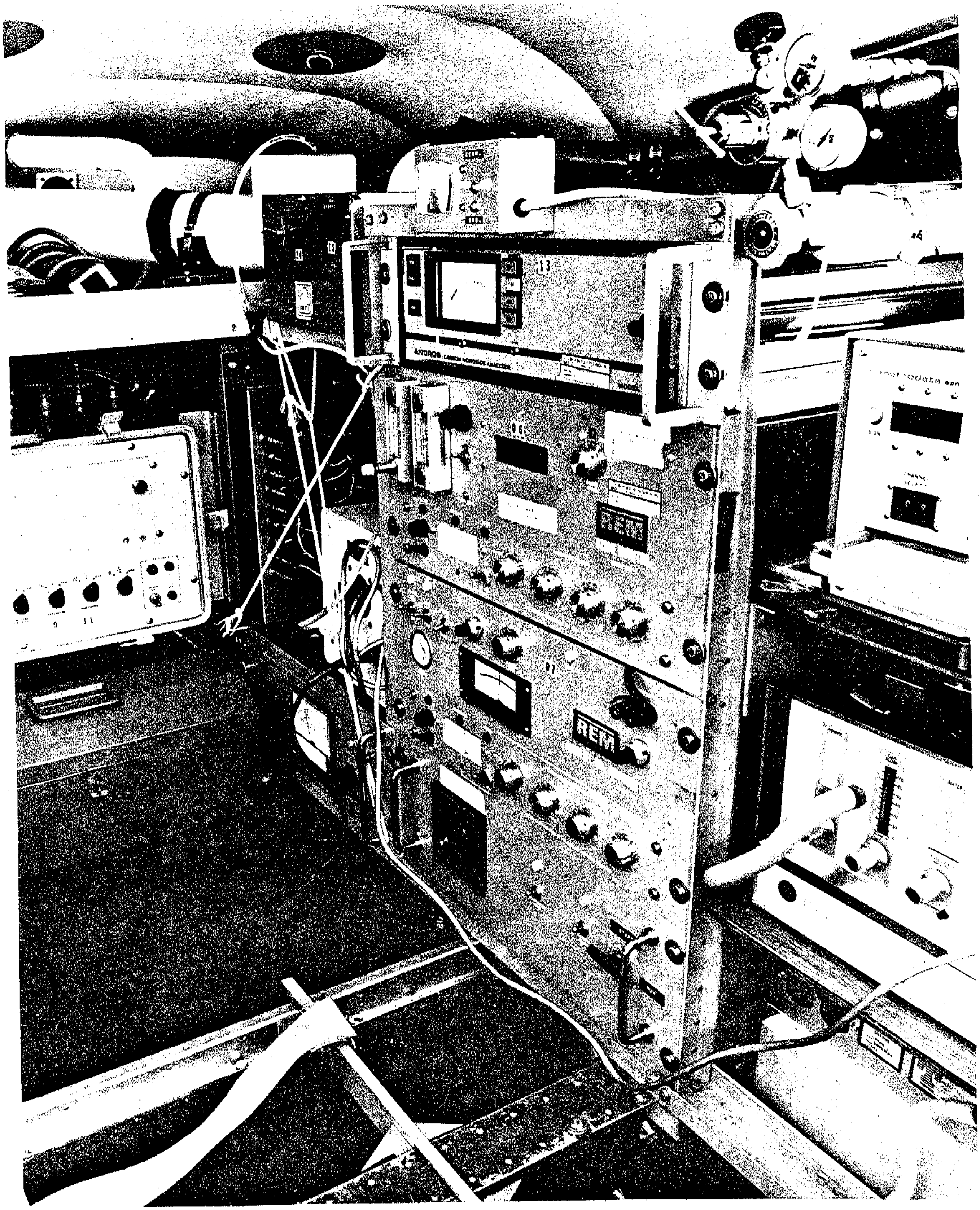

Fig. A-7 INSTRUMENT INSTALLATION OF CESSNA 310 top of the van, a six-foot extension, terminating in a double T fixture, was mounted, yielding a total sample length of about 12 feet. This column of air was renewed every four seconds. Each gas monitor drew its sample through teflon tubing connected in a T to the vertical sample column.

The condensation nuclei counter, thermometer, etc., were fed via Tygon tubing from the same air column. A second similar sample column fed the nephelometer. A third vertical column fed a Lundgren impactor. Figure A-8 shows a schematic of the left side of the van and Fig. A-9 is a schematic of the right side. Figure A-10 shows the overall floor plan from above. Figure A-11 is a photograph of the van and Fig. A-12 is a photograph of the inside of the van.

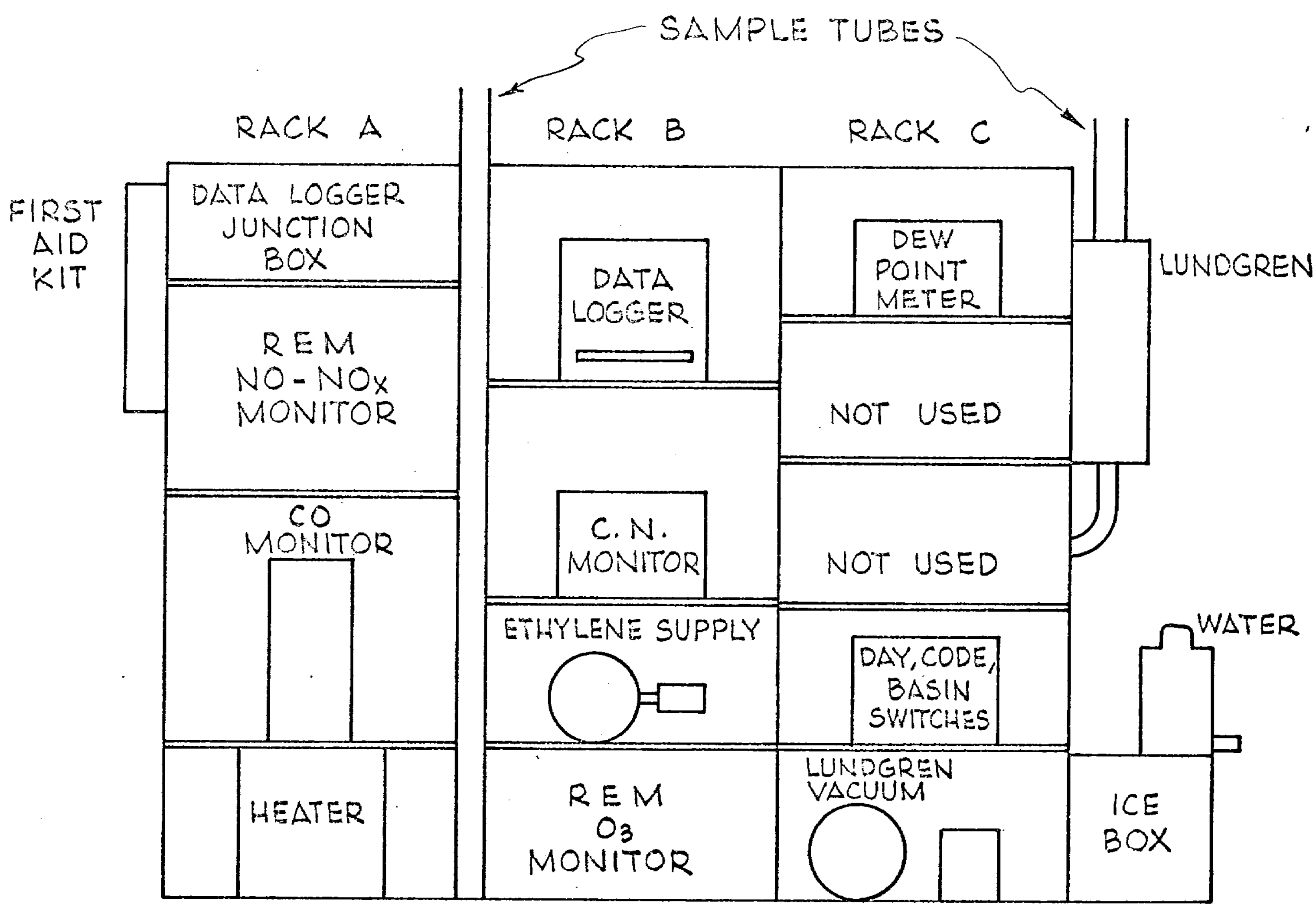

Fig. A-8. LEFT SIDE OF VAN FROM "OUTSIDE"

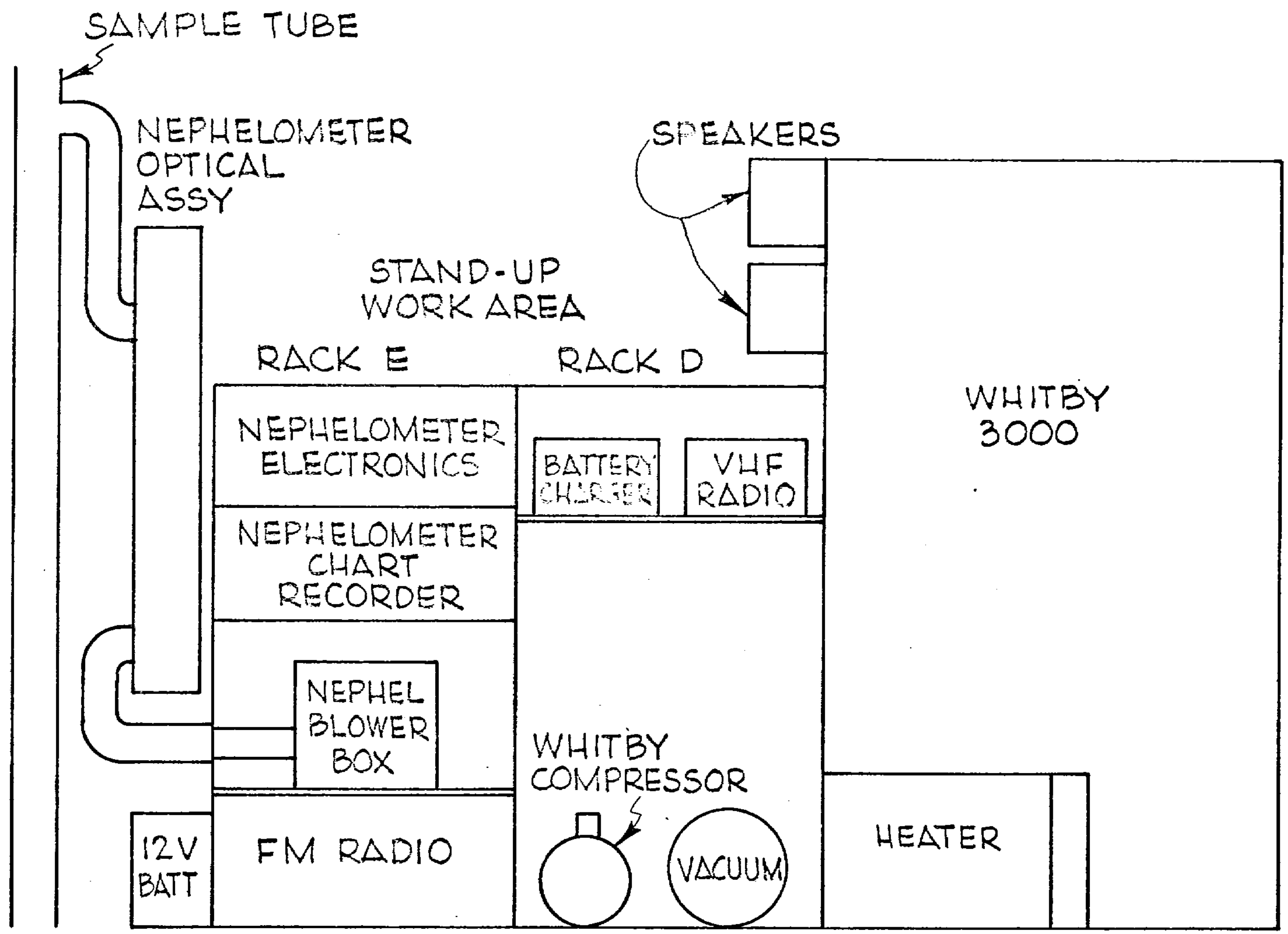

Fig. A-9. RIGHT SIDE OF VAN FROM THE INSIDE

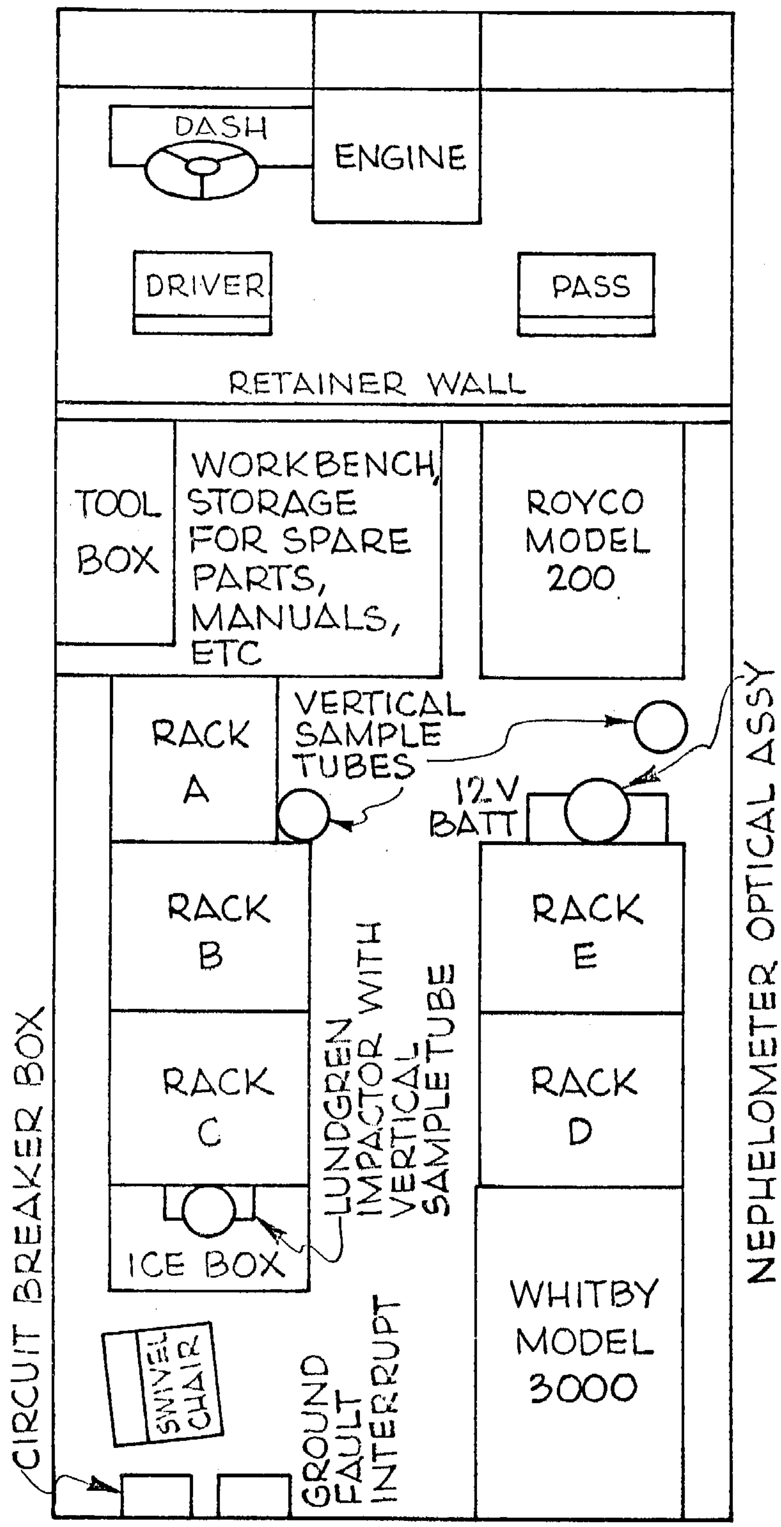

Fig. A-10. OVERALL FLOOR PLAN OF VAN

APPENDIX A
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Appendix B

INSTRUMENT CALIBRATION AND LIMITATIONS

This section discusses the calibrations and limitations of the instruments employed in the aircraft.

1. Ozone Monitors

The REM ozone monitors were among the most reliable of the instruments. They showed little zero drift with temperatures below 90°F and were rezeroed when the temperature was above 90°F. Zero points were checked daily during the sampling programs by turning off the sample pumps. The largest cause of error in ozone readings was variation in flow rate. The flow is measured by a ball-type flow meter which is accurate to only about ±5% and is controlled by a small vibrator pump which periodically changes its output slightly. The combined errors probably make the absolute values of ozone concentration accurate to ±0.005 ppm or ±15% of reading, whichever is higher. The variation within a single spiral, however, should be less than ±0.005 ppm or ±5% of reading.

2. NO_x Monitors

The NO_x monitors were found to maintain their span calibration extremely well with maximum variations during both programs of about 10% of reading. The flow is controlled by a critical orifice system which holds the mass flow quite constant, and the electronics are stable. The temperature stability of the instrument, however, was poor during the 1972 sampling program. The instruments depend upon a cooler to keep a photomultiplier tube at constant temperature. The instruments were essentially prototypes and were overly sensitive to temperature changes and experienced problems in the cooler circuitry. As a result, the zero would occasionally drift as much as 50% of scale. This problem was essentially alleviated before the 1973 program with the replacement of the stainless steel converters with molybdenum ones and the modification of the sample chamber to operate under a partial vacuum instead of at atmospheric pressure.

The NO_x data from the 1972 program have been artificially shifted to put the concentration equal to zero in regions of "clean" air. The variations in concentration during a spiral are usually representative, and much can be learned from them; but the absolute zero point is generally only a guess. Other questions about the steel converter make the absolute span calibrations questionable as well for 1972. In cases where an NO_x monitor was obviously malfunctioning during a flight, the data have been omitted. In questionable cases, it has been noted. This was not the case for the 1973 program where little data were lost due to zero point or calibration problems.

3. CO Monitors

During the 1972 program, the Andros CO monitors experienced problems almost identical to the NO_x monitors. The spans were checked every few weeks and were found to be constant to within 10%, but the zero point was found to be a strong function of temperature. The instruments were zeroed using a Hopcalite filter before each flight but would generally drift during a flight. The data were, therefore, handled in the same manner as the NO_x data.

Permanent installation of Hopcalite filters in both aircraft prior to the 1973 sampling program enabled observers to make periodic checks on the CO monitors before and during flights. This resulted in data of a higher caliber from the 1973 program than that obtained in 1972.

4. Integrating Nephelometers

The integrating nephelometers functioned quite reliably throughout both sampling programs. All data should be accurate to about $\pm 0.1 \times 10^{-4}$ m^{-1}, or 10% of reading, whichever is higher.

5. Condensation Nuclei Monitors

These instruments were not calibrated after they left the factory, but on their arrival at MRI they read within 15% of one another. At the end of each sampling program, they agreed within 30%. For this type of instrument, this is an acceptable margin of error, and except for altitude corrections, no adjustments were made to the data. These instruments experienced numerous mechanical problems, but malfunctions generally resulted in complete and obvious loss of data. On these occasions, CN data are deleted and noted.

6. Temperature and Humidity Sensors

The temperature sensors used in both programs functioned well and are accurate to about ±0.5°C. The humidity sensors used on the aircraft, however, suffered from slow time response and variations in calibration. In general, they are accurate to about ±5% RH but occasionally can be as much as 10% RH off. The degree of RH change during a single spiral, however, should be accurate to within 5% RH.

Appendix C

DATA PROCESSING SYSTEM - DETAILS

A. Data Processing Equipment

1. Computer and Related Hardware

The heart of this computing system (Fig. C-1) is a Digital Equipment Corporation PDP-8I general purpose digital computer. This computer comes equipped with 4096 words of core memory and an additional 4096 words of core memory were added for this project. The ASR-33 Teletype is the standard means of communicating with this computer.

In order to provide rapid access storage capacity for processing data and generating programs, two disk memory units were added to the system. Each DEC disk has a storage capacity of 32,000 words.

Two PERTEC standard synchronous write/synchronous read seven-channel digital tape drives are an essential part of the system, permitting storage of the data on magnetic tape. The Model 6x60 tape drive can handle up to 12-inch diameter reels (2400 ft of tape) and has a character transfer rate of 30 K Hz at 37.5 ips at a bit packing density of 800 cpi. The Model 7x20 is limited to seven-inch diameter reels (600 ft), has a character rate of 20 K Hz at 25 ips at a bit packing density of 800 cpi. These drives can read or write tapes in industry compatible format allowing interchange of tapes with other computer installations.

A Metrodata DL 622A tape cartridge reader was installed to process the data logger tapes. This unit was equipped with an internal interface for the PDP-8. A Metrodata GR-109 off line tape rewinder was purchased to speed processing. The final peripheral device is a Potter Instrument Company LP3000 line printer. This device prints at a rate of 135 lines per minute at 132 characters per line, permitting a fast printout of the data listings and plots in a wide page format.

2. System Software

The PDP-8 system at MRI is large enough to support a new operating system developed by Digital Equipment Corporation called the OS/8. OS/8 has a versatile keyboard monitor to control the flow of programs and a library of system programs permitting program development using FORTRAN or assembly language. These system programs include:

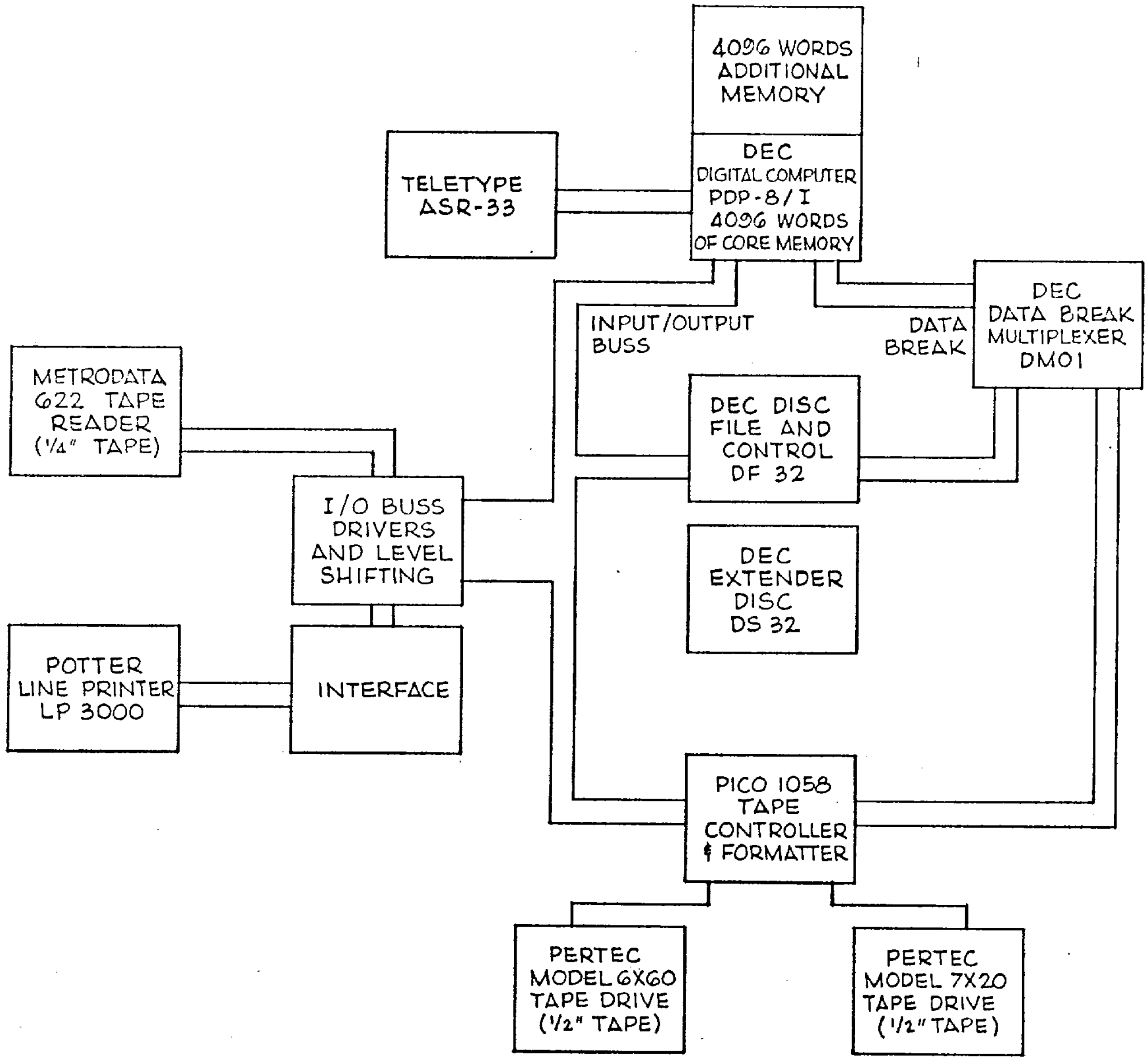


Fig. C-1. COMPUTER SYSTEM USED FOR DATA REDUCTION

(1) Symbolic Editor to create or modify source files for use as processing programs.

(2) Peripheral Interchange Program to transfer files between devices in the OS/8 system.

(3) FORTRAN compiler, SABR assembler, Linking Loader, and library function routines. The FORTRAN has chaining, device independent Input/Output, permits imbedded assembler language statements, and can be compiled, loaded, and executed with a single teletype command.

Special utility programs, called DSKSAV (disk save) and DSKRST (disk restore), are used to write the contents of the disk on magnetic tape or to read the magnetic tape and write on the disk. These programs allow a fast conversion from one set of programs to another (within 1/2 minute), minimizing dead time. A general purpose program to dump the contents of a magnetic tape on the line printer was also written to aid development of the tape handling programs.

B. Data Processing - 1972

This section details the data processing system in operation during the 1972 program. This system was subdivided into three sections:

(1) Fast turn around which results in line printer plots and listings, and data storage in an archive tape.

(2) The reduction of the data into a verified, edited tape.

(3) The use of the verified tape for data analysis.

In time sequence, the fast turn around phase was completed within a day after the flight, the production of the verified tape within a few months, and the data analysis will continue over a longer time scale.

1. Fast Turn Around Data Processing

The data flow for the fast turn around data processing is shown in Fig. C-2. The 1/4-inch data logger tape cartridges were checked out from the MRI computer center to the field personnel for the flight sequence. During the field measurements, a data sheet was maintained and an audio tape recorder was used to gather information

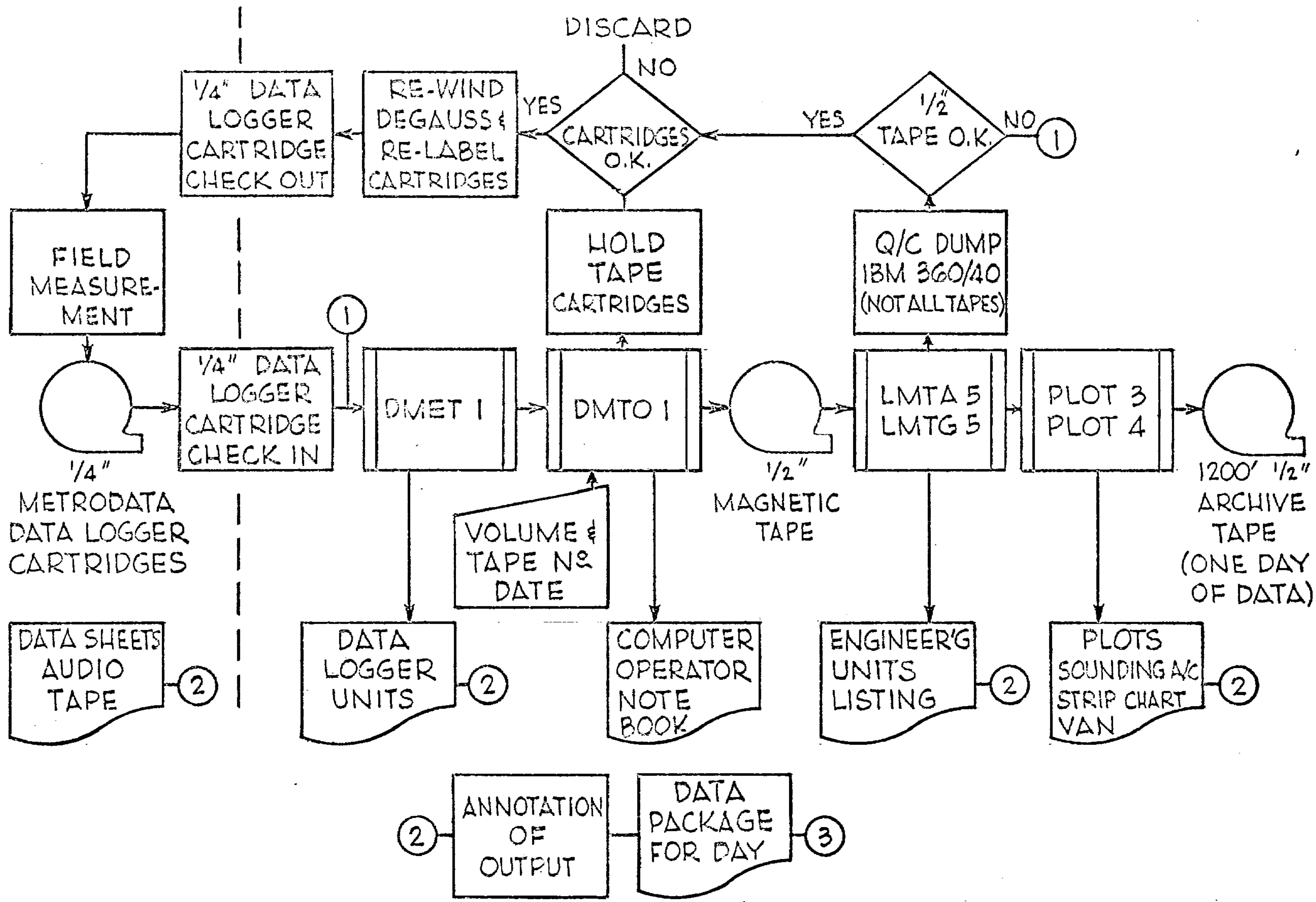
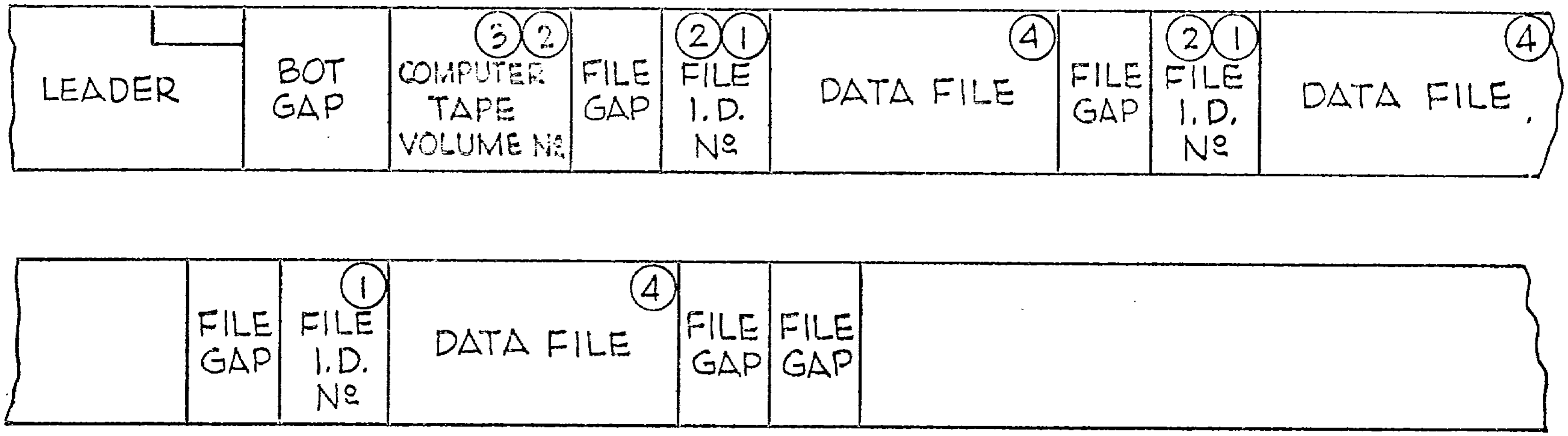


Fig. C-2. FAST TURN AROUND PROCESSING DATA FLOW which might be used in data reduction after the flights. At the end of the day, the tapes were checked in by the field personnel along with the data sheets and audio cassettes for each flight.

At MRI, the cartridges were rewound and dumped directly, with no editing, in data logger units (voltage x 2) to paper copy for backup and quality control of the data. Equipment malfunctions such as open circuits, intermittent operation, and many other problems could be detected at this point. An assembler language program DMET1 (Dump Metrodata) was used for this operation. The program reformatted the complementary BCD on the data logger tape into ASCII characters. The program DMTO1 (Dump Metrodata on Tape) was used to reformat, edit the data logger information and transfer to 1/2-inch magnetic tape. Any character that was not a number or a sign was edited out during the transfer. If more than four errors were edited from the data, a message was written on the Teletype.

The 1/2-inch tape was recorded in binary with a density of 800 BPI odd parity. The tape format is shown in Fig. C-3. Binary tape format was used for maximum packing of data on the tape and to minimize programming when reading the tapes on other computers. The identification headers facilitated location of the various flights for future data reduction. The number assigned to the Metrodata cartridge was used as the flight identification number for the data. The data were blocked records of ten Metrodata records of 20 three-digit integers with sign (12 bit computer word). All of the flights for one day (usually six) could be recorded on a 1200-ft reel of 1/2-inch tape, allowing each day to have a unique volume number.

The programs LMTA5 (List Magnetic Tape Airborne every five seconds) and LMTG5 (List Magnetic Tape Ground every five seconds) were used to list the data from the 1/2-inch magnetic tape every five seconds (a good time increment for viewing the data) in engineering units. An example of the output is shown in Fig. C-4. Identical programs were written early in the project to dump from the Metrodata data logger cartridge. Listing from the archival data tape was preferred to listing from the Metrodata cartridge because of the faster data transfer and the ability to compare these data to the data logger dump to verify that all of the data had been saved. An important system quality control step was to dump the archive tape on an IBM computer system to check the adjustment of the tape transport. This ensured that the tapes could be read at a later time on other computer systems.



(1) CONTAINS METRODATA CARTRIDGE Nº AND DATE INFORMATION WAS RECORDED.
METRODATA CARTRIDGE Nº IN I3 FORMAT – FIRST WORD IN RECORD. DATE RECORDED IN MONTH (I2), DAY (I2), AND YEAR (I2) – 2ND, 3RD, & 4TH WORDS IN RECORD.

(2) 20 - WORD RECORDS.

(3) TAPE VOLUME Nº IN I3 FORMAT – CONTAINED IN FIRST WORD IN RECORD.

(4) FILE CONTAINS RECORDS WHICH CONTAIN BLOCKS OF 10 METRODATA RECORDS (I.E. - 10 X 20 = 200 WORDS.)

Fig. C-3. TAPE FORMAT

RUN NUMBER ....
DATE OF RUN 9/20/72
TAPE NUMBER 77

3-D MAPPING PROJECT
LISTING OF AIRCRAFT DATA

DAY AND TIME DAY	HR	MIN	SEC	DME DIST (MI)	VOR (DEG)	NEPH	OZONE (PPM)	NITRIC OXIDE (PPM)	ALTITUDE (FEET)	TEMP (DEG C)	REL HUM (PCT)	TURB	COND NUCLEI (CN/CC)	CARBON MONOXIDE (PPM)	MODE/ EVENT	BASIN
18	8	25	7	-1.7	12	3.0	0.02	0.10	1000.	19.0	64	0.3	0.1 E+4	3	0 OFF	LA
18	8	25	10	-3.7	13	2.9	0.02	0.10	1000.	19.0	64	0.3	0.1 E+4	1	0 OFF	LA
18	8	25	15	-1.1	137	2.9	0.02	0.09	1010.	18.9	64	0.4	0.1 E+4	1	0 OFF	LA
18	8	25	20	-1.9	136	2.8	0.02	0.09	1000.	18.9	65	0.2	0.1 E+4	2	0 OFF	LA
18	8	25	25	-3.1	136	2.9	0.02	0.09	1000.	18.8	65	0.4	0.1 E+4	2	0 OFF	LA
18	8	25	30	-1.0	262	2.7	0.02	0.09	1010.	18.6	65	0.4	0.1 E+4	1	0 OFF	LA
18	8	25	35	-2.9	187	2.7	0.02	0.09	1010.	18.6	65	0.5	0.0 E+4	0	0 OFF	LA
18	8	25	40	-1.6	217	2.7	0.02	0.09	1010.	18.6	65	0.5	0.0 E+4	0	0 OFF	LA
18	8	25	45	-1.2	146	2.6	0.02	0.09	1010.	18.6	66	0.3	0.0 E+4	0	0 OFF	LA
18	8	25	50	0.5	280	2.8	0.02	0.08	1000.	18.6	67	0.7	0.0 E+4	2	0 OFF	LA
18	8	25	55	42.1	122	2.9	0.02	0.08	1000.	18.5	66	1.0	0.0 E+4	0	0 OFF	LA
18	8	26	0	20.7	93	2.7	0.02	0.08	1000.	18.5	66	0.6	0.0 E+4	0	0 OFF	LA
18	8	26	5	20.9	132	2.6	0.02	0.09	1010.	18.5	66	0.7	0.0 E+4	0	0 OFF	LA
18	8	26	10	20.7	101	2.7	0.02	0.08	1010.	18.5	67	0.7	0.0 E+4	0	0 OFF	LA
18	8	26	15	20.7	130	2.7	0.02	0.08	1010.	18.4	66	0.4	0.0 E+4	0	0 OFF	LA
18	8	26	20	20.7	236	3.0	0.02	0.08	1020.	18.4	66	0.5	0.0 E+4	0	0 OFF	LA
18	8	26	25	20.5	135	2.8	0.02	0.08	1020.	18.3	66	0.6	0.0 E+4	0	0 OFF	LA
18	8	26	30	20.7	250	2.8	0.02	0.08	1020.	18.3	66	0.8	0.0 E+4	1	0 OFF	LA
18	8	26	35	21.4	208	2.8	0.02	0.09	1020.	18.3	66	0.6	0.0 E+4	0	0 OFF	LA
18	8	26	40	20.6	171	2.7	0.02	0.08	1030.	18.3	66	0.6	0.0 E+4	1	0 OFF	LA
18	8	26	45	20.7	225	2.8	0.02	0.08	1030.	18.3	66	0.7	0.0 E+4	0	0 OFF	LA
18	8	26	50	20.2	232	2.9	0.02	0.08	1030.	18.2	66	0.7	0.0 E+4	0	0 OFF	LA
18	8	26	55	21.5	223	2.9	0.02	0.08	1030.	18.1	67	0.4	0.0 E+4	0	0 OFF	LA
18	8	27	0	21.1	128	2.9	0.02	0.08	1030.	18.2	67	0.4	0.0 E+4	1	0 OFF	LA
18	8	27	5	21.0	216	2.8	0.02	0.08	1040.	18.2	67	0.5	0.0 E+4	0	0 OFF	LA
18	8	27	10	21.0	210	2.8	0.02	0.08	1040.	18.2	67	0.6	0.0 E+4	1	0 OFF	LA
18	8	27	15	21.1	229	2.8	0.02	0.08	1050.	18.2	67	0.4	0.0 E+4	1	0 OFF	LA
18	8	27	20	21.0	230	2.8	0.02	0.07	1050.	18.2	67	0.4	0.0 E+4	0	0 OFF	LA
18	8	27	25	20.9	160	2.8	0.02	0.07	1050.	18.2	67	0.5	0.0 E+4	0	0 OFF	LA
18	8	27	30	20.9	153	2.8	0.02	0.08	1050.	18.3	67	0.6	0.0 E+4	0	0 OFF	LA
18	8	27	35	20.9	157	2.8	0.02	0.08	1050.	18.3	67	0.9	0.0 E+4	0	0 OFF	LA
18	8	27	40	20.6	137	2.8	0.02	0.08	1050.	18.2	67	1.4	0.0 E+4	1	0 OFF	LA
18	8	27	45	20.9	129	2.8	0.02	0.08	1050.	18.2	67	1.4	0.0 E+4	0	0 OFF	LA
18	8	27	50	20.7	200	2.7	0.02	0.08	1050.	18.2	67	1.4	0.0 E+4	1	0 OFF	LA
18	8	27	55	21.2	146	2.7	0.02	0.07	1060.	18.2	67	1.6	0.0 E+4	1	0 OFF	LA
18	8	28	0	21.0	68	2.7	0.02	0.07	1060.	18.2	67	1.7	0.0 E+4	1	0 OFF	LA
18	8	28	5	20.9	268	2.6	0.02	0.08	1050.	18.2	68	1.6	0.0 E+4	0	0 OFF	LA
18	8	28	10	20.6	253	2.6	0.02	0.07	1050.	18.2	68	1.7	0.0 E+4	1	0 OFF	LA
18	8	28	15	21.1	41	2.7	0.02	0.07	1050.	18.2	68	1.8	0.0 E+4	0	0 OFF	LA
18	8	28	20	21.4	207	2.9	0.02	0.07	1050.	18.2	68	1.6	0.0 E+4	0	0 OFF	LA
18	8	28	25	21.2	185	2.8	0.02	0.07	1060.	18.1	68	1.4	0.0 E+4	1	0 OFF	LA
18	8	28	30	21.5	105	2.8	0.02	0.07	1060.	18.2	68	1.1	0.0 E+4	1	0 OFF	LA
18	8	28	35	21.4	143	2.8	0.02	0.07	1060.	18.2	68	1.0	0.0 E+4	1	0 OFF	LA
18	8	28	40	20.7	163	2.8	0.02	0.07	1060.	18.2	68	0.8	0.0 E+4	1	0 OFF	LA

Fig. C-4. EXAMPLE OF OUTPUT OF THE PROGRAM LMTA5

The data were then plotted on the line printer using the plot programs. The PLOT3 program was used to plot the airborne data. The data were usually sorted into an array corresponding to 100-ft altitude increments. An example of the output is shown in Fig. C-5. The program PLOT4 was used to plot the ground van data. The van data were plotted in "strip chart" form with the option of any averaging time. An example of the output is shown in Fig. C-6.

All the outputs were annotated with basic information such as location, date, time, altitudes, and any malfunctions or problems with instruments. The annotated computer output, flight maps, and data sheets were assembled into data packages for the day. This data package was combined with the description of the meteorology to form the basic analysis package.

2. Data Reduction to Produce an Edited Tape

The quick turn around data and all other information pertinent to the flights were used to verify the data on the archive tape. Instrument malfunctions and operational problems were identified. This information formed an input into the data reduction process. The data flow for this segment is shown in Fig. C-7.

The program CLEAN is a general purpose data correction program. The data in any channel could be corrected with a slope and offset. The slopes and offsets were punched into paper tape for automatic operation, and the corrected data were transferred to a 600-ft reel of magnetic tape. Only the data recorded during the spirals were corrected and transferred to the edited tape. The program has options to use either the event mark or time to locate spirals on the tape, allowing use on tapes with a wide variety of recorder and operational problems.

The pressure altitude measured by the AIP is converted to an altimeter altitude using the NACA standard atmosphere equation and the aircraft altimeter observations to correct for the offset (barometric pressure). The O_3 and CO readings were corrected for density changes with altitude by factors of $(\sqrt{\rho_0/\rho})$ and (ρ_0/ρ), respectively. The base level pressure is 1013.25 mb and the base temperature is 15°C for the reference density corresponding again to the NACA standard atmosphere.

The format for the edited tape was quite similar to that shown in Fig. C-4 for the archive tape with the exception that before each spiral there was a block containing information about the spiral such as the offsets and slopes used to adjust the data, the mixing depth for the spiral, and a spiral identification number. There is sufficient information on a tape to allow a future user to reconstruct the raw data if necessary and to identify the spiral location.

September 20, 1972 - Corona - 500' to 3000'

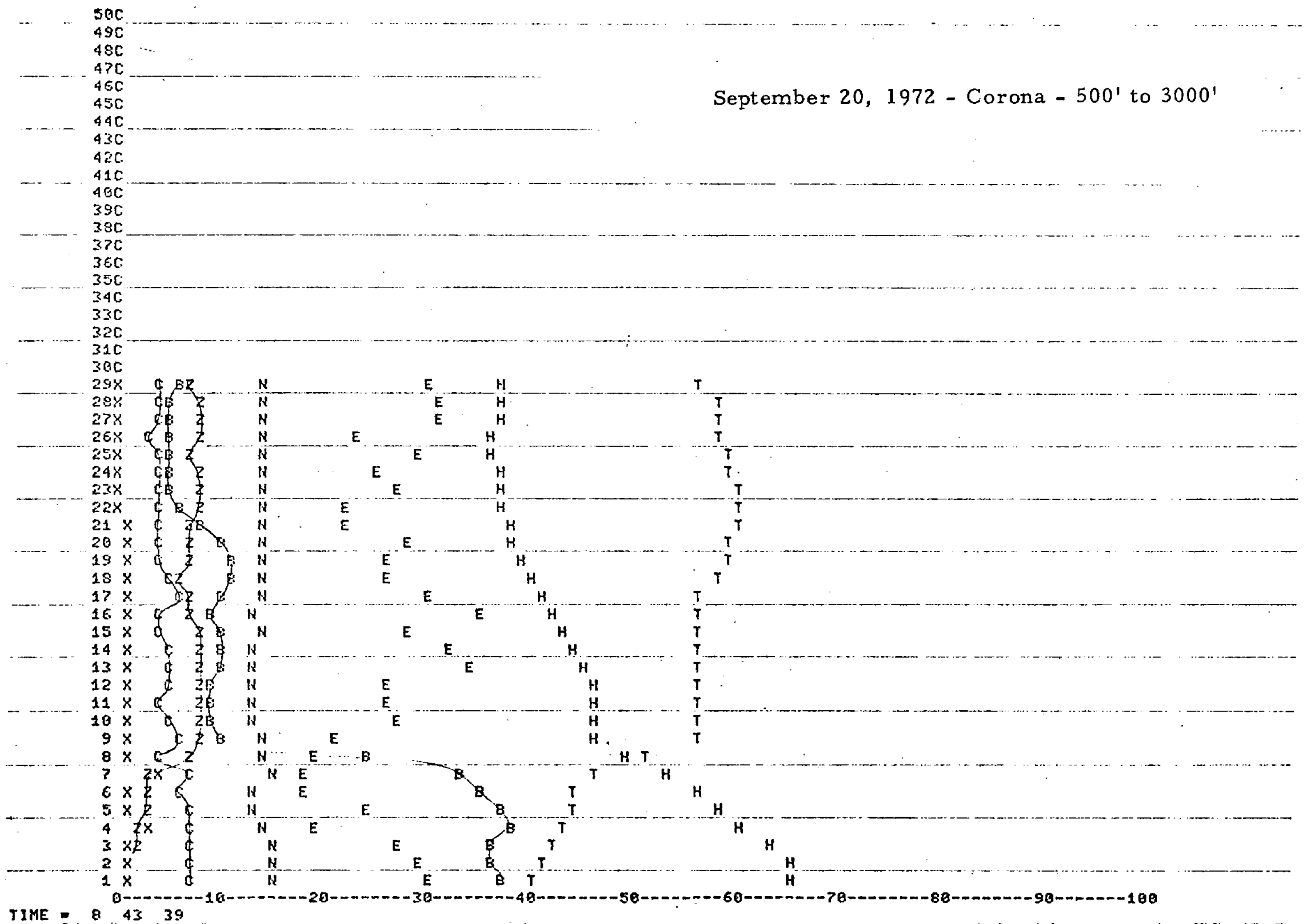


Fig. C-5. EXAMPLE OF OUTPUT OF THE PROGRAM PLOT3

PLOT OF 3-D MAPPING PROJECT GROUND VAN DATA.

STARTING DATE -- 9/21/72 --- CARTRIDGE NO. 82

S = WIND SPEED
D = WIND DIRECTION
B = NEPHOLOMETER
Z = OZONE
N = NITRIC OXIDE
T = TEMPERATURE
X = CONDENSATION NUCLEI
C = CARBON MONOXIDE
P = DEW POINT TEMPERATURE
* = OVERLAID VALUES

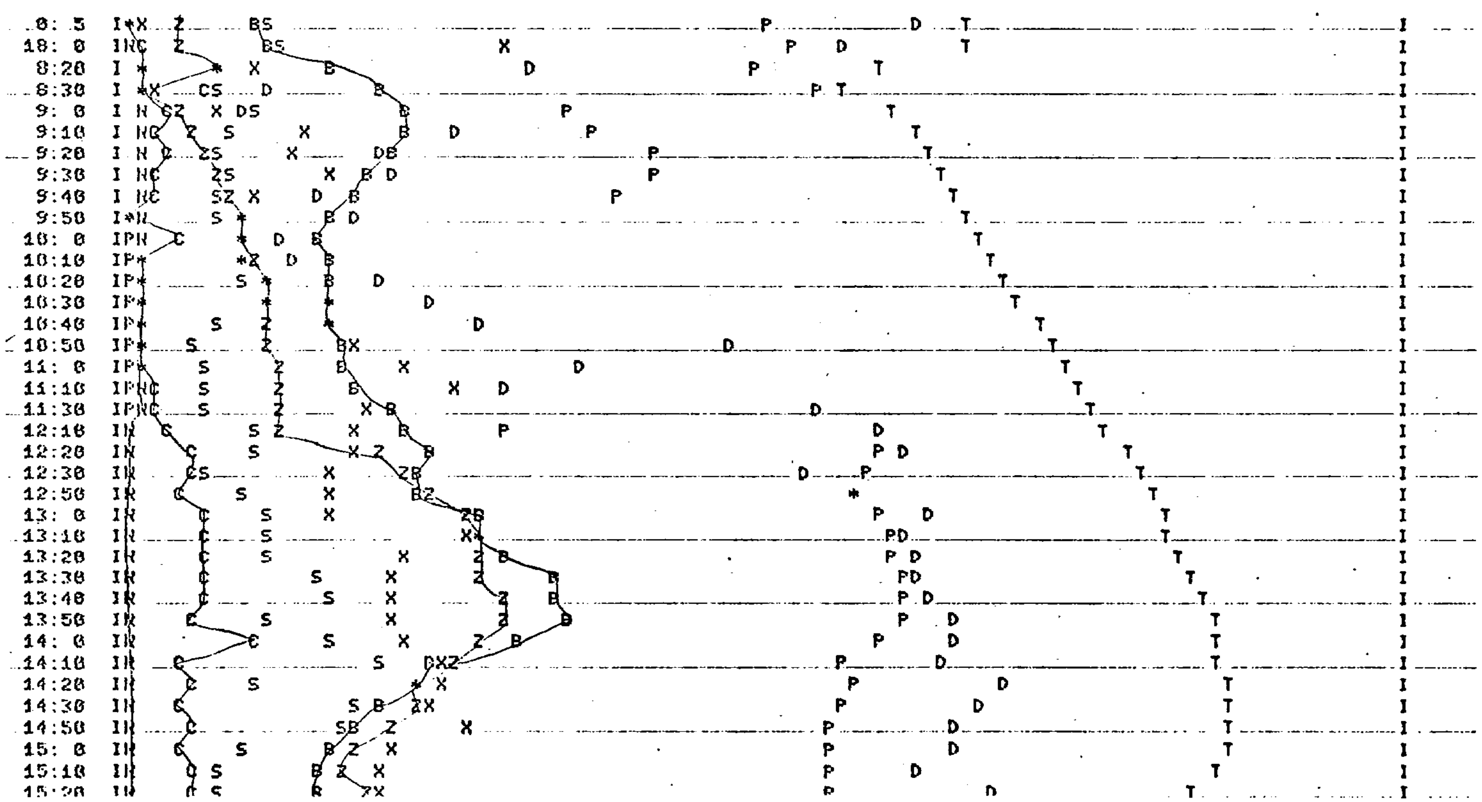


Fig. C-6. EXAMPLE OF OUTPUT OF THE PROGRAM PLOT4

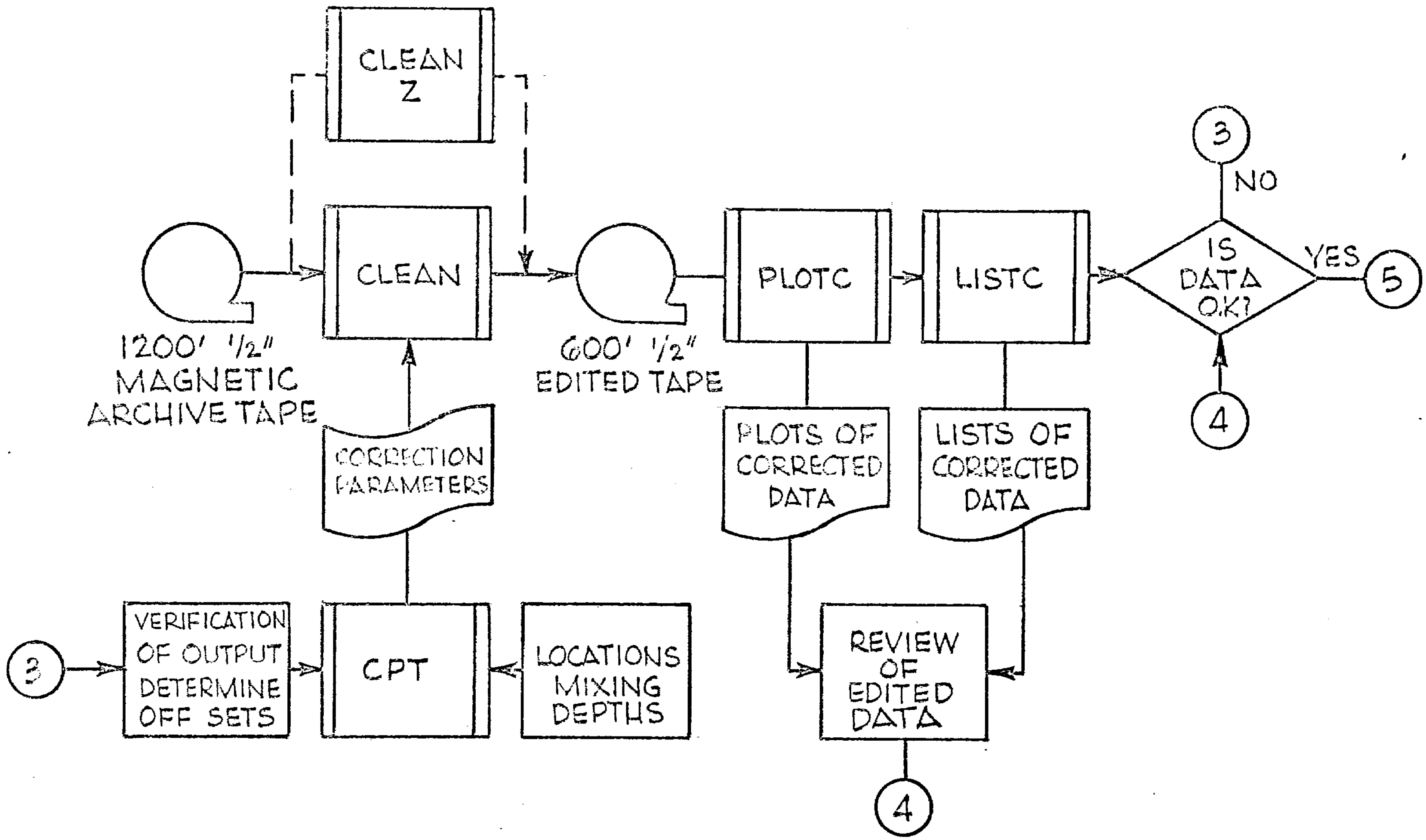


Fig. C-7 DATA REDUCTION TO EDITED TAPE

The punching of the paper tape containing the data corrections is very time-consuming if performed manually (each channel has two entries - offset and slope - plus the identification entries for a total of 50 entries for each spiral). The program CPT was written to computer punch the paper tape with the entry of only a few key parameters from the teletype. For most cases, the only correction on offsets necessary were for NO_x and CO. For unusual malfunctions, the proper inputs on the paper tape could be hand corrected.

Programs PLOTC and LISTC are modifications of PLOT3 and LMTA5 written to read the edited tape. The output for this program was used for a final inspection of the data as a check of the processing. An example of the output from PLOTC is shown in Fig. C-8 indicating the correction of offsets and refinement of data by the CLEAN program. If the data appear to be valid, they are released to the data analysis segment. If not, the data are returned to the verification step and the data reexamined.

3. Data Analysis and Production of Contour Maps

This final segment of data reduction is shown in Fig. C-9. The 600-ft reel containing the edited and verified data for one day of flights can now be used directly for statistical analysis such as that described in Chapters V and VIII. The tapes can also be used to produce publication quality plots of the sounding on a line plotter or CRT tube.

Another data reduction function performed occasionally was that of producing constant altitude isopleth maps of air pollution concentrations for the flights. The stratification program was used to select data from the clean data tape at 500-ft increments averaged over ± 50 ft. Another tape was written containing the averaged data. A listing of this tape was made for quality control of the contents of the tape and to aid the hand plotting of contour maps for the Bay Area and the San Joaquin Valley. The stratified data tape was used as input data to the program CONTUR (used at the CIT computer center by W. White) which was used occasionally to produce isopleth maps for the Los Angeles Basin.

C. Data Processing - 1973

As mentioned in Section III-D, the data processing procedures for the 1973 sampling program incorporated revisions to the 1972 system due to the implementation of new instruments, channel assignments, and sampling procedures. The entire 1973 system is shown in Fig. C-10. Procedures for checking out cartridges and logging them in after field use were essentially the same as they were in 1972. After rewinding the cartridges and assigning a volume number to each sampling day, the

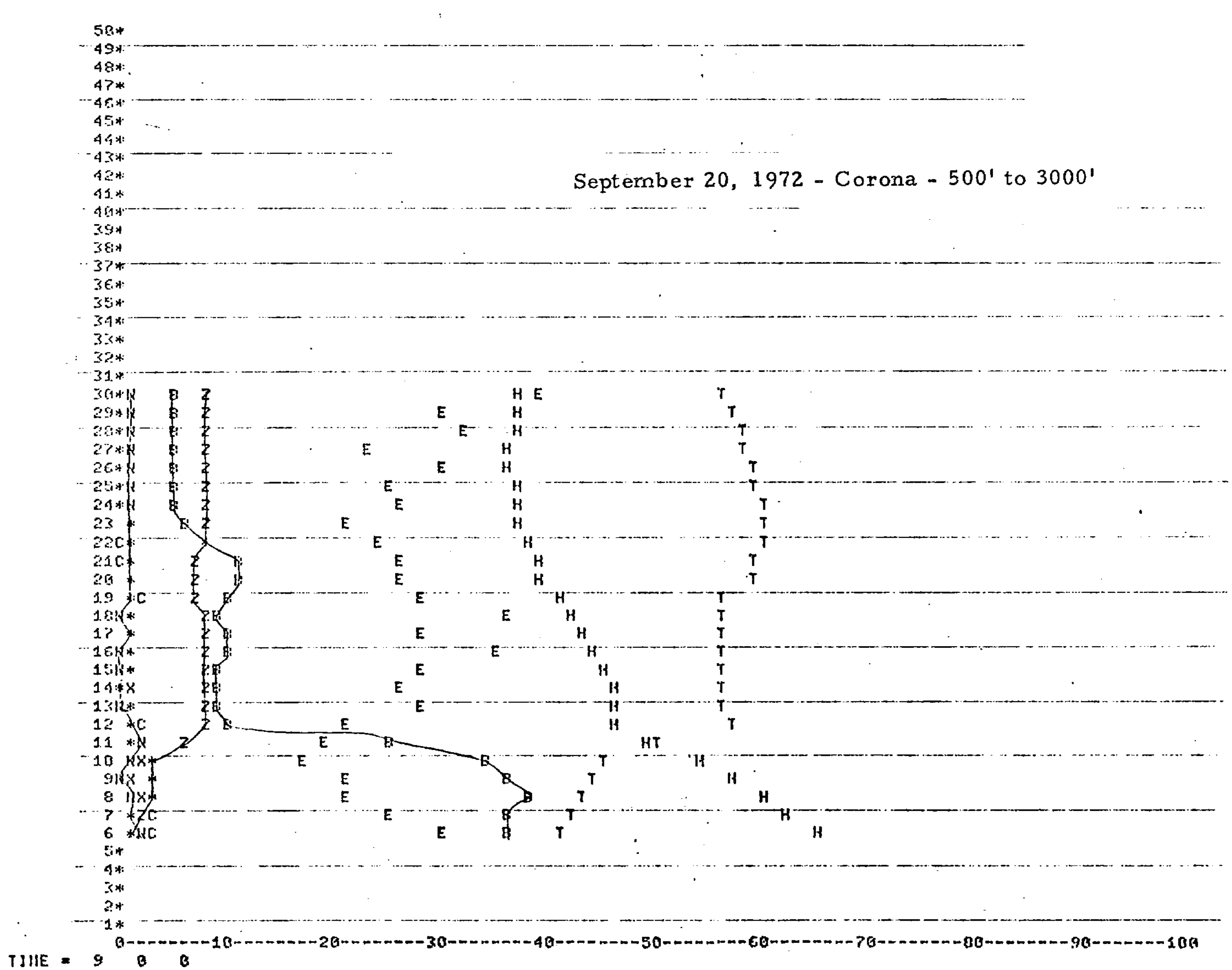


Fig. C-8. EXAMPLE OF OUTPUT OF THE PROGRAM PLOTC USING CLEANED DATA. NOTE THE ALTITUDE AND OFFSET CORRECTIONS.

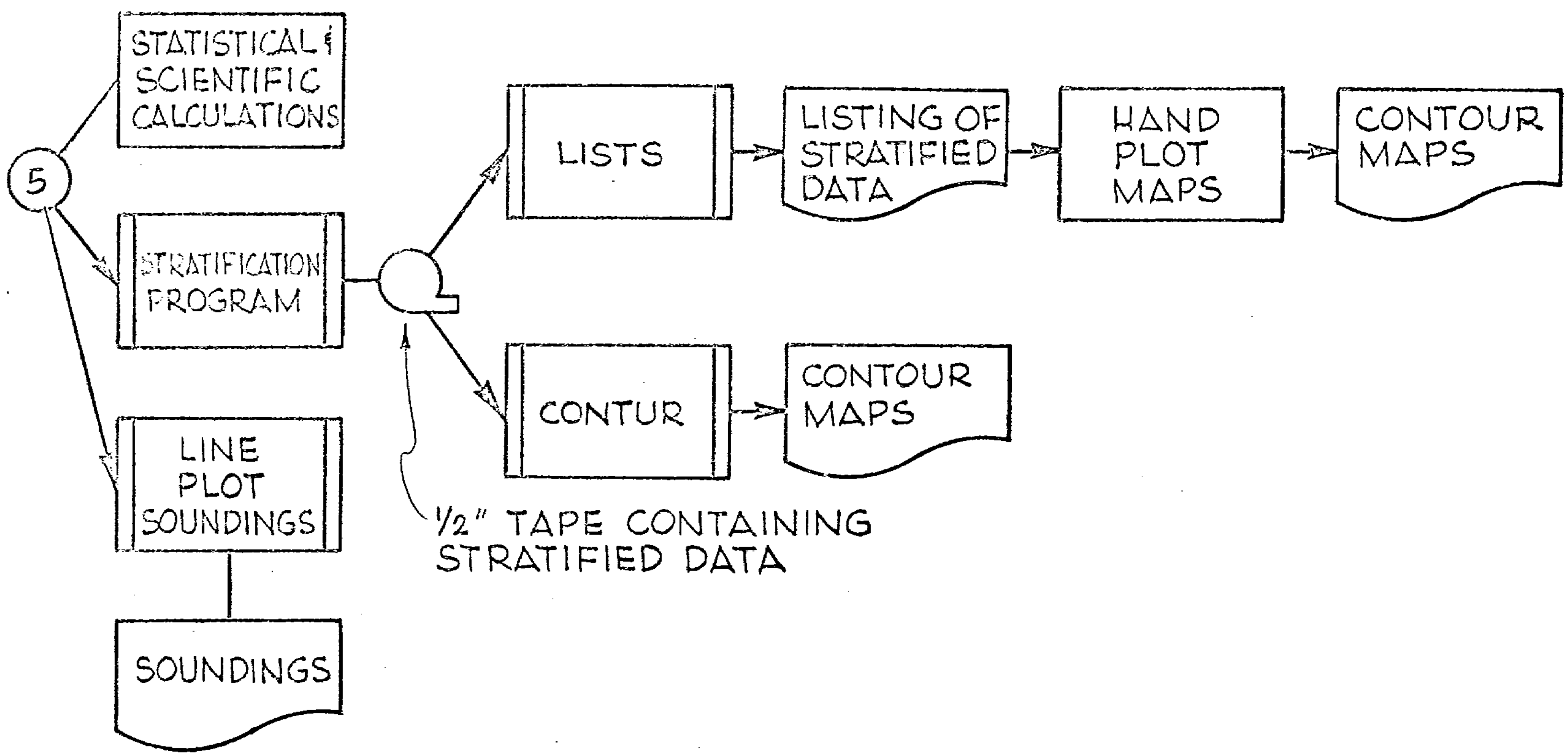


Fig. C-9. DATA ANALYSIS AND PRODUCTION OF CONTOUR MAPS

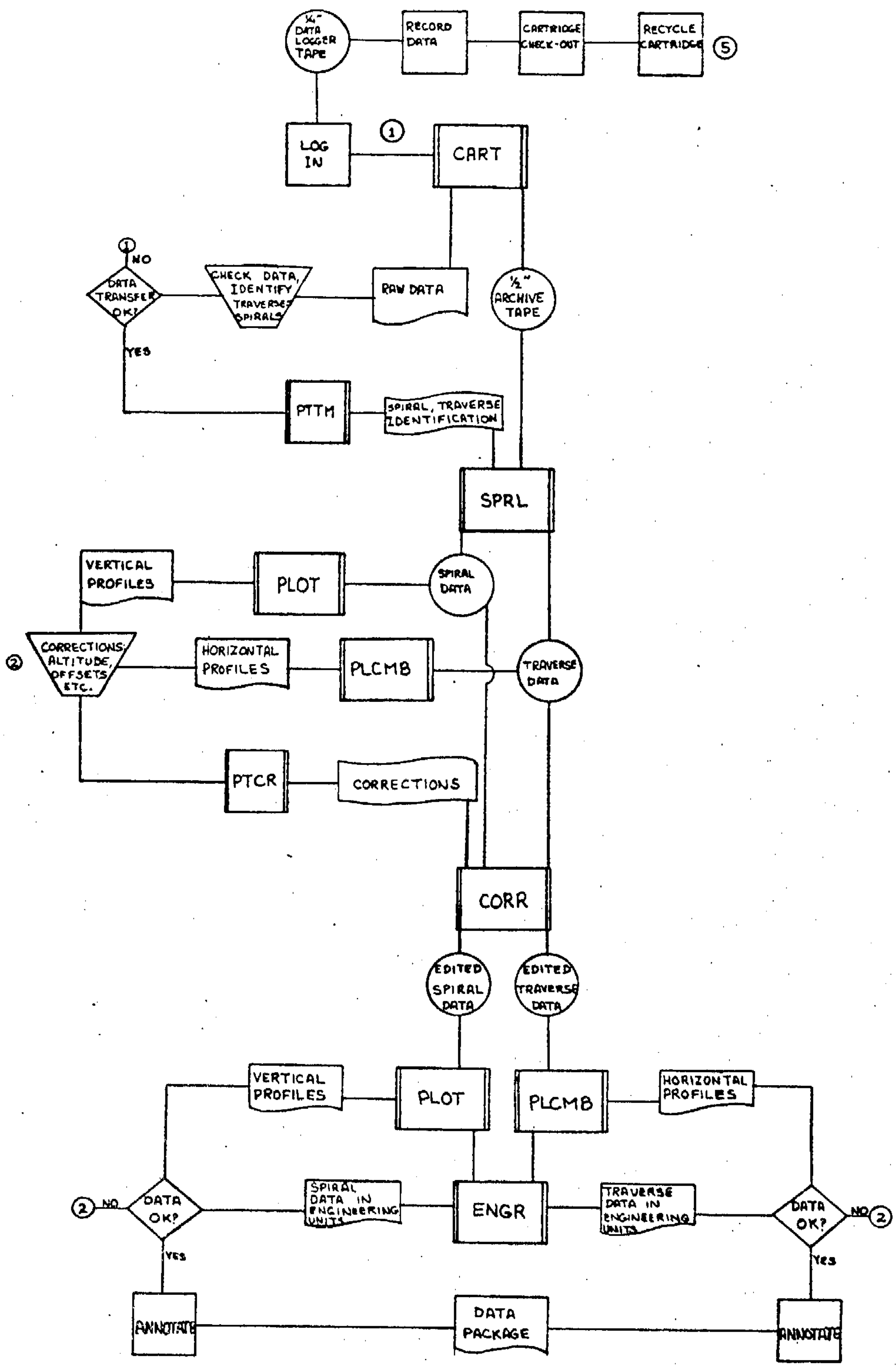


Fig. C-10. AIR QUALITY DATA PROCESSING FLOW CHART

LISTING OF RAW DATA
CARTRIDGE NO. 632
RECORDED 7/26/73

80	1	631	199	273	323	51	-127	39	387	200	162	415	117	32	46	153	134	0	704	0 1
80	3	631	199	273	323	51	-127	41	382	200	155	415	109	30	46	153	131	0	24	0 6
80	6	631	199	273	323	51	-127	64	389	200	158	415	98	30	46	153	126	0	369	0 11
80	8	631	199	273	323	51	-127	112	408	200	125	415	90	29	43	153	123	0	620	0 16
80	11	631	199	273	323	51	-128	153	403	200	100	415	81	29	45	153	119	0	63	0 21
80	13	631	199	273	323	51	-126	205	411	200	99	415	76	32	51	153	116	0	314	0 26
80	16	631	199	273	323	51	-125	250	402	200	98	415	70	25	18	153	112	0	676	0 31
80	18	631	199	273	323	51	-127	269	413	200	99	415	71	26	8	153	109	0	16	0 36
80	21	631	199	273	324	52	-128	362	422	200	97	415	67	21	6	153	105	0	384	0 41
80	23	631	199	273	324	52	-126	503	412	200	95	415	55	22	4	153	102	0	639	0 46
80	26	631	199	272	324	52	-127	635	414	200	93	415	47	24	2	153	98	0	24	0 51
80	28	631	199	272	324	52	-125	676	408	200	91	415	45	22	5	153	96	0	283	0 56
80	31	631	199	272	324	52	-125	742	426	200	94	415	48	22	3	153	92	0	264	0 61
80	33	631	199	272	324	52	-127	704	420	200	95	415	44	23	4	153	89	0	-10	0 66
80	36	631	199	272	324	52	-127	519	427	200	98	415	42	20	3	153	85	0	-13	0 71
80	38	631	199	272	324	52	-128	366	438	200	108	415	43	22	4	153	82	0	-12	0 76
80	41	631	199	272	324	52	-127	201	419	200	127	415	39	22	3	153	78	0	-9	0 81
80	43	631	199	272	325	53	-127	132	428	200	136	415	37	21	5	153	76	0	-11	0 86
80	46	631	199	272	325	52	-127	75	425	200	178	415	33	26	4	153	72	0	-12	0 91
80	48	631	199	272	325	53	-127	57	418	200	196	415	33	26	2	153	69	0	-15	0 96
80	51	631	199	272	325	52	-127	37	377	200	252	415	32	31	1	153	65	0	-14	0101
80	53	631	199	272	326	52	-127	33	347	200	291	415	32	28	6	153	63	0	56	0106
80	56	631	199	272	326	53	-127	31	363	200	239	415	29	28	4	153	58	0	417	0111
80	58	631	199	272	326	52	-127	30	364	200	201	415	33	29	150	153	56	0	683	0116
80	101	631	199	272	326	53	-127	45	398	200	165	415	34	28	749	153	53	0	135	0121
80	103	631	199	272	326	52	-127	67	414	200	133	415	22	32	387	153	50	0	382	0126
80	106	631	199	272	326	53	-128	137	425	200	105	415	20	36	[illegible]	153	47	0	718	0131
80	108	631	199	272	326	53	-126	163	433	200	102	415	20	31	529	153	44	0	-15	0136
80	111	631	193	272	326	53	-127	164	432	200	101	414	19	28	625	153	41	0	-15	0141
80	113	631	199	271	326	53	-127	159	435	200	105	415	13	26	658	153	38	0	-15	0146
80	116	631	199	271	326	53	-128	167	437	200	106	415	14	22	702	153	35	0	-16	0151
80	119	631	199	272	326	53	-127	167	443	200	104	415	13	21	681	153	32	0	-7	0156
80	121	631	199	272	326	53	-127	108	443	200	100	415	11	21	673	153	29	0	-14	0161
80	123	631	199	271	326	53	-127	73	440	200	101	415	14	22	672	153	26	0	-1	0166
80	126	631	199	271	326	53	-127	45	443	200	101	415	16	25	722	153	23	0	0	0171
80	128	631	199	271	327	53	-127	36	442	200	99	415	16	25	567	153	20	0	252	0176
80	131	631	199	271	326	53	-127	26	443	200	97	415	16	28	223	153	17	0	611	0181
80	134	631	199	272	326	53	-127	38	440	200	114	415	20	28	186	153	15	0	861	0186
80	136	631	199	272	327	54	-127	37	425	200	131	415	12	31	182	153	11	0	72	0191
80	139	631	199	272	327	54	-127	42	423	200	150	415	8	32	180	153	9	0	346	0196
80	142	631	199	272	327	54	-127	55	422	200	157	415	10	34	184	153	6	0	708	0201
80	144	631	199	272	327	54	-127	44	420	200	133	415	12	38	190	153	4	0	53	0206
80	147	631	199	272	327	54	-127	38	409	200	129	415	6	39	191	153	1	0	158	0211
80	149	631	199	272	327	54	-127	41	426	200	126	415	0	35	192	153	0	0	415	0216
80	152	631	199	272	327	54	-127	47	416	200	119	415	4	40	194	153	-3	0	786	0221
80	154	631	193	272	327	54	-127	48	411	200	111	415	5	38	191	153	-5	0	128	0226
80	157	631	199	272	327	54	-127	44	415	200	102	415	8	36	190	153	-9	0	484	0231
80	159	631	199	272	327	54	-127	28	417	200	112	415	8	36	187	153	-12	0	151	0236
80	202	631	199	272	327	54	-127	34	423	200	115	415	3	35	187	153	-15	0	516	0241
80	204	631	193	272	327	54	-127	35	419	200	96	415	1	35	187	153	-18	0	188	0246
80	201	631	199	272	327	54	-127	38	420	200	99	415	6	35	184	153	-20	0	477	0251
80	203	631	199	272	327	54	-127	34	422	200	103	414	8	33	179	153	-23	0	26	0256
80	206	631	199	272	327	54	-127	25	410	200	107	414	8	35	180	153	-27	0	396	0261
80	208	631	199	272	327	54	-127	21	415	200	107	415	10	36	174	153	-29	0	657	0266
80	211	631	199	272	328	54	-127	21	408	200	106	415	8	37	179	153	-32	0	46	0271
80	213	631	199	272	328	54	-127	21	406	200	99	415	8	36	173	153	-35	0	300	0276
80	216	631	199	272	328	54	-127	16	407	200	97	414	13	38	172	153	-39	0	640	0281
80	218	631	199	272	328	54	-127	14	401	200	92	415	13	37	177	153	-41	0	109	0286
80	221	631	199	272	328	54	-127	13	406	200	90	415	11	36	[illegible]	153	-45	0	248	0291
80	223	631	199	272	328	54	-127	13	400	200	91	415	8	37	170	153	-47	0	507	0296
80	226	631	193	273	328	54	-127	12	400	200	92	415	8	35	171	153	-51	0	787	0301
80	228	631	199	273	328	54	-127	11	402	200	96	415	4	37	169	153	-54	0	203	0306
80	231	631	193	273	328	54	-127	11	405	200	95	415	0	41	165	153	-58	0	560	0311
80	233	631	199	273	328	54	-127	27	397	200	93	415	2	39	165	153	-60	0	805	0316
80	236	631	199	273	328	54	-126	82	392	200	85	415	1	38	163	153	-65	0	234	0321
80	238	631	199	272	329	54	-126	114	402	200	78	415	4	38	163	153	-68	0	482	0326
80	241	631	199	272	328	54	-127	148	417	200	76	415	2	37	161	153	-71	0	109	0331
80	243	631	199	272	329	54	-127	143	424	200	75	415	1	38	164	153	-74	0	132	0336
80	246	631	199	272	329	54	-127	143	422	200	76	415	4	35	161	153	-77	0	442	0341
80	248	631	199	272	329	54	-127	140	421	200	77	414	1	35	161	153	-80	0	699	0346
80	251	631	199	272	329	54	-126	152	411	200	77	414	-3	37	158	153	-84	0	90	0351
80	253	631	199	272	329	54	-127	142	410	200	77	415	-1	36	159	153	-87	0	353	0356
80	256	631	199	272	329	54	-127	139	418	200	76	415	14	39	160	153	-90	0	731	0361
80	258	631	199	272	329	54	-127	97	421	200	76	414	24	37	159	153	-93	0	29	0366
80	300	631	199	272	329	54	-127	83	419	200	76	415	31	34	159	153	-96	0	76	0371
80	302	631	199	272	329	54	-127	83	425	200	76	415	33	34	159	153	-99	0	110	0376
80	305	631	199	273	329	54	-126	103	431	200	76	415	34	34	156	153	-103	0	156	0381
80	308	631	199	273	329	54	-127	130	415	200	76	415	38	37	160	153	-105	0	83	0386
80	311	631	199	273	329	54	-126	115	413	200	77	415	39	40	158	153	-109	0	447	0391
80	313	631	193	273	329	54	-126	76	406	200	77	415	38	39	161	153	-112	0	692	0396
80	316	631	199	273	329	54	-126	83	423	200	76	415	45	41	158	153	-116	0	133	0401
80	318	631	199	273	329	54	-127	94	442	200	73	415	48	40	162	153	-118	0	387	0406
80	321	631	199	273	329	55	-126	109	451	200	91	415	47	38	161	153	-122	0	750	0411
80	323	631	199	273	329	55	-125	65	443	200	146	415	44	35	167	153	-125	0	73	0416
80	326	631	199	273	329	55	-127	59	452	200	162	415	43	30	174	153	-128	0	447	0421
80	329	631	199	273	329	55	-127	65	461	200	117	415	47	33	161	153	-131	0	688	0426
80	331	631	199	272	328	54	-127	69	457	200	93	415	54	37	162	153	-134	0	-1	0431
80	333	631	199	272	329	55	-128	93	467	200	85	415	44	37	161	153	-137	0	5	0436

Fig. C-11. CART PROGRAM OUTPUT

Appendix D

SAMPLING MISSIONS - 1972, 1973 PROGRAMS

The following tables, D-1 and D-2, summarize the sampling missions of both the 1972 and 1973 programs. Included are comments regarding instrument operations and special studies.

Table D-1

SAMPLING MISSIONS - 1972

Date	Basin	Base	Weather	Aircraft	Route	Time (PDT)	Comments
4/26/72	L. A.	Cable Airport	Clear, light winds up to 10 knots from SW.	205	A	0835 - 0954	DME, NO monitor and CO monitor not installed.
					A	1339 - 1607	Temperature sensor failed before first flight.
4/28/72	L. A.	Cable Airport	Morning overcast clearing by 0900.	205	C	0841 - 1000	DME, NO monitor not installed.
			Light and variable winds from SW.		C	1102 - 1241	
			Moderate pollution		C	1453 - 1625	
7/24/72	L. A.	El Monte Airport	Navy Van Operating by 1753 near FAA Tower at Airport				
			Clear with haze in morning, light winds from SW.	205	A	1130 - 1323	NO monitor not installed
7/25/72	L. A.	El Monte Airport	Broken clouds at 10, 000 ft. until 1145. Haze layers from 1145 until 1500, light winds from SW.	205	A	1000 - 1120 1441 - 1618	Van wind system failed at 0630. FAA data used as backup. Missions used to train Navy personnel.
7/26/2	L. A.	El Monte Airport	Clear - calm winds until 1100 - light winds to 15 knots from SW.	205	C	0814 - 0945	Day of Metronics FP tracer study.
					B	1119 - 1248	
					A	1501 - 1623	
				310	A	0835 - 0954	
					A	1108 - 1142	28 VDC to 110 VAC inverter failed after 35 mins.
				Navy Van Shut Down by 1630			

Table D-1 (cont.)

Date	Basin	Base	Weather	Aircraft	Route	Time (PDT)	Comments
8/2/72	L. A.	El Monte	Navy Van Operating by 1730. New MRI Wind System Had Been Installed.				
8/3/72	L. A.	El Monte Airport	High fog at 1000 ft. which burned off at 1015. Light winds from SW.	205	B	1317 - 1505	Limited sampling because of weather conditions.
			Partially cloudy beginning at 1651.	310	A	1340 - 1521	
8/4/72	L. A.	El Monte Airport	High fog at 2000 ft. which burned off at 1000. Partly cloudy.	205	C C	1050 - 1245 1536 - 1712	The flights were delayed until mid-morning because of fog.
			Light winds from SW.	310	A A	1052 - 1233 1515 - 1650	
				Navy Van Shut Down at 1727			
8/10/72	S. F.	Alameda Naval Air Stn.	Clear - Wind from S up to 18 knots.	Navy Van Operating at 1315			
8/11/72	S. F.	Alameda	Clear - Wind from SSW from 8 to 15 knots.	205	East East East	0900 - 1036 1233 - 1358 1557 - 1730	
				310	West West West	0936 - 1132 1230 - 1407 1608 - 1615	28 VDC to 110 VAC inverter failed.
				Navy Van Shut Down at 1745			

Table D-1 (cont.)

Date	Basin	Base	Weather	Aircraft	Route	Time (PDT)	Comments
8/2/72	L. A.	El Monte	Navy Van Operating by 1730. New MRI Wind System Had Been Installed.				
8/3/72	L. A.	El Monte Airport	High fog at 1000 ft. which burned off at 1015. Light winds from SW.	205	B	1317 - 1505	Limited sampling because of weather conditions.
			Partially cloudy beginning at 1651.	310	A	1340 - 1521	
8/4/72	L. A.	El Monte Airport	High fog at 2000 ft. which burned off at 1000. Partly cloudy. Light winds from SW.	205	C	1050 - 1245	The flights were delayed until mid-morning because of fog.
					C	1536 - 1712	
				310	A	1052 - 1233	
					A	1515 - 1650	
				Navy Van Shut Down at 1727			
8/10/72	S. F.	Alameda Naval Air Stn.	Clear - Wind from S up to 18 knots.	Navy Van Operating at 1315			
8/11/72	S. F.	Alameda	Clear - Wind from SSW from 8 to 15 knots.	205	East	0900 - 1036	
					East	1233 - 1358	
					East	1557 - 1730	
				310	West	0936 - 1132	
					West	1230 - 1407	
					West	1608 - 1615	28 VDC to 110 VAC inverter failed.
				Navy Van Shut Down at 1745			

Table D-1 (cont.)

Date	Basin	Base	Weather	Aircraft	Route	Time (PDT)	Comments
8/21/72	S. F.	Alameda		Navy Van Operating at 1815			No NO_x data from van.
8/22/72	S. F.	Alameda Naval Air Sta.	Thin scattered to broken clouds at 25,000 ft. Highs in 70's. Calm in early morning. Wind in afternoon 10 to 20 kts from W (from N at southern end of bay).	205 205 205	Eastern Eastern Western	0824-1015 1218-1404 1608-1721	No data from first flight. No output from NO_x monitor.
8/23/72	S. F.			Navy Van Shut Down at 1800			
8/24/72	S. F.	Alameda		Navy Van Operating at 1850			No NO_x data from van.
8/25/72	S. F.	Alameda Naval Air Sta.	Patchy late night and early morning low clouds with ceilings at 1000 ft clearing by late morning. Highs in 70's. Afternoon wind from W to N at 5 to 15 knots. At S. F. Intl., wind from E. Typical S. F. weather.	205 205 205 310 310 310	Eastern Eastern Eastern Western Western Western	0806-0956 1204-1342 1604-1751 0831-0941 1203-1309 1630-1743	
				Navy Van Shut Down at 1805			
8/28/72	L. A.	El Monte		Navy Van Operating at 1618			No NO_x data from van.

Table D-1 (cont.)

Date	Basin	Base	Weather	Aircraft	Route	Time (PDT)	Comments
8/29/72	L. A.	Cable Airport	Hot. High overcast (~10,000 ft) formed in late afternoon. Winds mostly from SW, S to 15 kts.	205	B	0824-1024	NO_x monitor removed from plane. DME inoperative
				205	B	1207-1407	
				205	B	1559-1808	
				310	A	0833-0955	CNM not working on first flight.
				310	A	1246-1425	VOR inoperative.
				310	A	1644-1807	
				Navy Van Shut Down at 1745			
9/6/72	S. J. V.	Bakersfield		Navy Van Operating at 1725			
9/7/72	S. J. V.	Fresno	Typical clear day. Isolated clouds over mountains. High temperatures in low 90's. Varying winds 5 to 15 kts.	205	Southern	0850-1228	
				205	Southern	1515-1831	
				310	Northern	0907-1242	
				310	Northern	1439-1804	
				Navy Van Shut Down at 1815			NO_x monitor inoperative.
9/12/72	S. J. V.	Bakersfield		Navy Van Operating at 1050			No NO_x data from van.
9/13/72	S. J. V.	Fresno	Typical clear day. Highs in high 80's. Winds from W to N at 5 to 10 kts.	205	Southern	0829-1147	
				205	Southern	1420-1735	
				310	Northern	0826-1100	CNM inoperative.
				310	Northern	1504-1740	
9/14/72				Navy Van Shut Down at 0916			
9/19/72	L. A.	Southwest Museum		Navy Van Operating at 1745			NO_x monitor inoperative until 9/21.

Table D-1 (cont.)

Date	Basin	Base	Weather	Aircraft	Route	Time (PDT)	Comments
9/20/72	L. A.	Cable Airport	Clear. Winds from WSW from 5 to 15 kts. High in 70's	205	B	0829-1023	
				205	B	1204-1401	
				205	B	1547-1755	
				310	A	0834-1037	
				310	A	1205-1430	
				310	A	1555-1846	
9/21/72	L. A.	Cable Airport	Generally clear. Light clouds in afternoon. Winds mostly from W and SW, 5 to 15 kts.	205	C	0821-0948	CNM inoperative on second and third flights.
				205	C	1227-1353	
				205	C	1600-1829	
				310	B	0819-1049	
				310	B	1223-1434	
				310	B	1550-1747	
				Navy Van Shut Down at 1750			
9/26/72	L. A.	El Monte Airport		Navy Van Operating at 1019			No NO_x data from van.
	L. A.	Cable Airport	Late night and early morning low clouds. Very hazy. Max. temperature in upper 70's. Winds from S to SW, 5 to 15 kts.	205	C	0830-1101	
				205	C	1453-1702	
				310	A	0848-1136	
				310	A	1509-1809	
9/27/72	L. A.	Cable	Patchy late night and early morning low clouds. Very hazy. High overcast by noon. Highs in mid-70's. Winds from W to SW, 10 to 20 kts.	205	C	0814-1040	CNM inoperative on second flight.
				205	C	1609-1800	
				310	B	0900-1147	
				310	B	1501-1740	
				Navy Van Shut Down at 1756			

Table D-1 (cont.)

Date	Basin	Base	Weather	Aircraft	Route	Time (PDT)	Comments
9/28/72	L. A.	Cable Airport	Early morning low clouds. Scattered middle to high clouds in early afternoon. Highs in mid-70's. Winds from S to W, 5 to 15 kts.	205	Special	1650-1922	
9/29/72	L. A.	Cable Airport	Scattered to broken clouds. Highs in low 80's. Winds from W to SW, 5 to 15 kts.	205	Special	1345-1605	
10/4/72	L. A.	El Monte Airport		Navy Van Operating at 1823			No NO_x data from van.
10/5/72	L. A.	Cable Airport	Light Santa Ana condition. No marine inversion. High temperatures from mid-80's to low 90's. Winds from 5 to 15 kts.	205 205 205 310 310 310	C C C A A A	0829-1031 1242-1440 1612-1807 0841-1115 1241-1504 1610-1835	CNM not installed on first flight, possibly not working on second and third flights. CO monitor not installed.
10/6/72	L. A.	Cable Airport	Light Santa Ana condition. Maximum temperatures in high 80's to low 90's. Winds 5 to 15 kts.	205 205 205 310 310 310	C C C B B B	0842-1003 1202-1321 1557-1712 0841-1054 1221-1414 1603-1749	No CO data. Suspect CNM working intermittently.
				Navy Van Shut Down at 1819			

Table D-1 (cont.)

Date	Basin	Base	Weather	Aircraft	Route	Time (PDT)	Comments
10/11/72	L.A.	Cable Airport	Scattered middle to high clouds. Highs in upper 70's. Winds 5 to 15 kts.	205	Special	1109-1300	
		El Monte Airport		Navy Van Operating at 1425			No NO_x data from van.
10/12/72	L.A.	Cable Airport	High cloud cover early in day. Max. temperatures in mid-70's. Winds 5 to 15 kts.	205	C	0815-1005	
				205	C	1221-1412	
				205	C	1610-1757	
				310	A	0817-1013	No CNM data.
				310	A	1216-1403	
				310	A	1612-1817	
10/13/72	L.A.	Cable Airport	Morning fog, cleared by afternoon. Generally clear. Maximum temperatures in upper 70's. Winds mostly from SW, 5 to 15 kts.	205	C	0802-0917	
				205	C	1159-1335	
				205	C	1548-1714	
				310	B	0804-0950	No CNM data.
				310	B	1157-1337	
				310	B	1553-1733	
				Navy Van Shut Down at 1721			
10/17/72	L.A.	El Monte Airport		Navy Van Operating at 1615			No NO_x data from van.
10/18/72	L.A.	Cable Airport	Hazy overcast 2000-3000 ft ceilings by early evening. Scattered showers and thunderstorms. Max. temp. in high 60's. Winds mostly from E, 5 to 10 kts.	205	C	0837-0957	No NO_x data. Light rain on third flight. Suspect CNM not working.
				205	C	1200-1320	
				205	C	1605-1717	
				310	A	0847-1029	NO_x monitor removed. CO monitor and CNM failed on second flight. Some rain on second flight.
				310	A	1213-1359	

Table D-1 (cont.)

Date	Basin	Base	Weather	Aircraft	Route	Time (PDT)	Comments
10/19/72	L. A.	Cable Airport	Low and middle clouds throughout LA area. Scattered showers. Maximum temperatures in low 70's. Winds from WSW, 5 to 15 kts.	205 205	B B	0804-0940 1203-1335	CO failed before first flight. No flights by 310 due to instrument failures. Suspect CNM not working.
				Navy Van Shut Down at 1542			
			Rain at El Monte 10/18 (1405) until early morning, 10/19.				
10/24/72	L. A.	El Monte Airport		Navy Van Operating at 1242			No NO_x data from van.
	L. A.	Cable Airport	Heavy morning fog; clear skies later in day. Maximum temperatures in mid-	205 205 205	C C C	0805-0945 1207-1438 1552-1753	NO_x monitor not installed. Suspect CNM not working.
			70's (Santa Ana condition beginning in late evening). Winds during day from SW, 2 to 12 kts.	310 310	B B	1218-1418 1604-1753	NO_x monitor not installed. Suspect CNM not working.
10/25/72	L. A.	Cable Airport	Clear skies, except for patchy ground fog in morning. Some	205 205	C C	1219-1344 1547-1717	NO_x monitor not installed. Suspect CNM not working.
			strong NE winds in mountain and canyon areas. Winds mostly from SW, 5 to 15 kts.	310 310 310	A A A	0854-1045 1234-1429 1559-1800	
				Navy Van Shut Down at 1820			

Table D-1 (cont.)

Date	Basin	Base	Weather	Aircraft	Route	Time (PDT)	Comments
11/1/72	L. A.	Cable Airport	Scattered to thin broken high clouds. Max. temperatures in high 60's. Winds mostly from SW, 5 to 15 kts.	205 205 205	C Special C	0824-0959 1213-1330 1546-1722	NO_x monitor not installed. CO inoperative on third flight. Second flight was a mapping of points at 2500 and 5000 ft along a special route. Suspect CNM not working.
11/2/72	L. A.	Cable Airport	Scattered high clouds in morning. Max. temperatures from low to mid-70's. Winds during the day mostly from SW, 5 to 12 kts, evening winds from NW, up to 5 kts.	205 205	Special Special	1410-1604 2153-2350	No NO_x or CO data. Suspect CNM not working.
11/1/72	Desert	China Lake		Navy Van Operating at 1341			No NO_x data from van.
11/2/72	Desert	China Lake	Nice clear day.	310 310 Navy Van Shut Down at 1700	Desert Desert	0801-1041 1353-1639	
4/6/73	L. A.	Cable Airport	Clear with morning haze and coastal low clouds. Light, variable winds. High temperatures in upper 60's to low 70's.	205 310	C C C B B B	0825-1021 1247-1451 1558-1742 0825-1037 1247-1440 1609-1751	

Table D-2

SAMPLING MISSIONS - 1973

Date	Basin	Base	Aircraft	Route	Time (PDT)	Comments
7/3/73	Oxnard	Ventura	205	Special	1300-1700	Ventura Power Plant Plume Study
7/11/73	L. A.	Cable	Navy van operating by 1200 at Brackett Airport			
			205	Riverside	0806-1009	
				Riverside	1214-1421	
				Riverside	1553-1750	
			310	North	0804-1020	
				North	1214-1413	
				North	1550-1716	
7/12/73	L. A.	Cable	205	Riverside	1217-1408	CO monitor on 310 noisy with zero drift
				Riverside	1552-1744	
			310	North	1158-1352	
				North	1550-1744	
			Navy van shut down by 1745			
7/18/73	L. A.		Navy van operating by 0813 at Brackett Airport			
		Cable	205	Riverside	0809-0956	NO_x out on 205
				Riverside	1218-1411	
				Riverside	1551-1738	
			310	South	0802-0940	
				South	1216-1358	
				South	1552-1733	

Table D-2 (cont.)

Date	Basin	Base	Aircraft	Route	Time (PDT)	Comments
7/19/73	L. A.	Cable	205	Riverside	0803-0935	O_3 sample pump doesn't
				Riverside	1159-1333	work on low AC voltage
				Riverside	1610-1754	on 205
			310	North	0805-0953	CO monitor inoperative
				North	1158-1410	in 310
				North	1609-1756	
			Navy van shut down by 1731			
7/23/73	L. A.		Navy van operating by 1820 at Brackett Airport			
7/25/73	L. A.	Cable	205	North	0813-1025	Smog alert called
				North	1216-1428	
				North	1632-1813	
			310	Riverside	0814-0844	
				Riverside	1330-1458	
				Riverside	1646-1843	
7/26/73 7/27/73	L. A.	Ontario	205	Riverside	2128-2336	24 hour sampling of
				Riverside	0032-0215	Riverside Route
				Riverside	0415-0550	
			310	Riverside	0804-0952	
				Riverside	1150-1317	
				Riverside	1550-1734	
			Navy van shut down by 0920, 7/27/73			
7/31/73	L. A.		Navy van operating by 1543 at Brackett Airport			

Table D-2 (cont.)

Date	Basin	Base	Aircraft	Route	Time (PDT)	Comments
8/2/73	L. A.	Cable	310	North	0819-1120	
				Riverside	1215-1433	
				Riverside	1552-1813	
8/3/73	L. A.	Cable	205	Riverside	0827-1037	Metronics tracer study support
				North	1310-1535	
				Riverside	1640-1847	
			310	Riverside	0813-0912	
				South	1339-1521	
				South	1640-1830	
8/4/73	L. A.	Cable	205	Riverside	1130-1349	Metronics tracer study support
				Riverside	1505-1718	
			Navy van shut down by 2055			
8/9/73	L. A.	Cable	Navy van operating by 1800 at Brackett Airport			
			205	Riverside	0818-1025	Inverter problems on 205
					1204-1239	
			310	North	0817-1038	
				North	1213-1414	
8/10/73	L. A.	Cable	205	Special	1228-1328	Special flight
				Riverside	1548-1745	
			310	South	0807-0940	
				North	1208-1358	
				South	1614-1750	
			Navy van shut down by 1820			
8/15/73	L. A.		Navy van operating by 1230 at Brackett Airport			

Table D-2 (cont.)

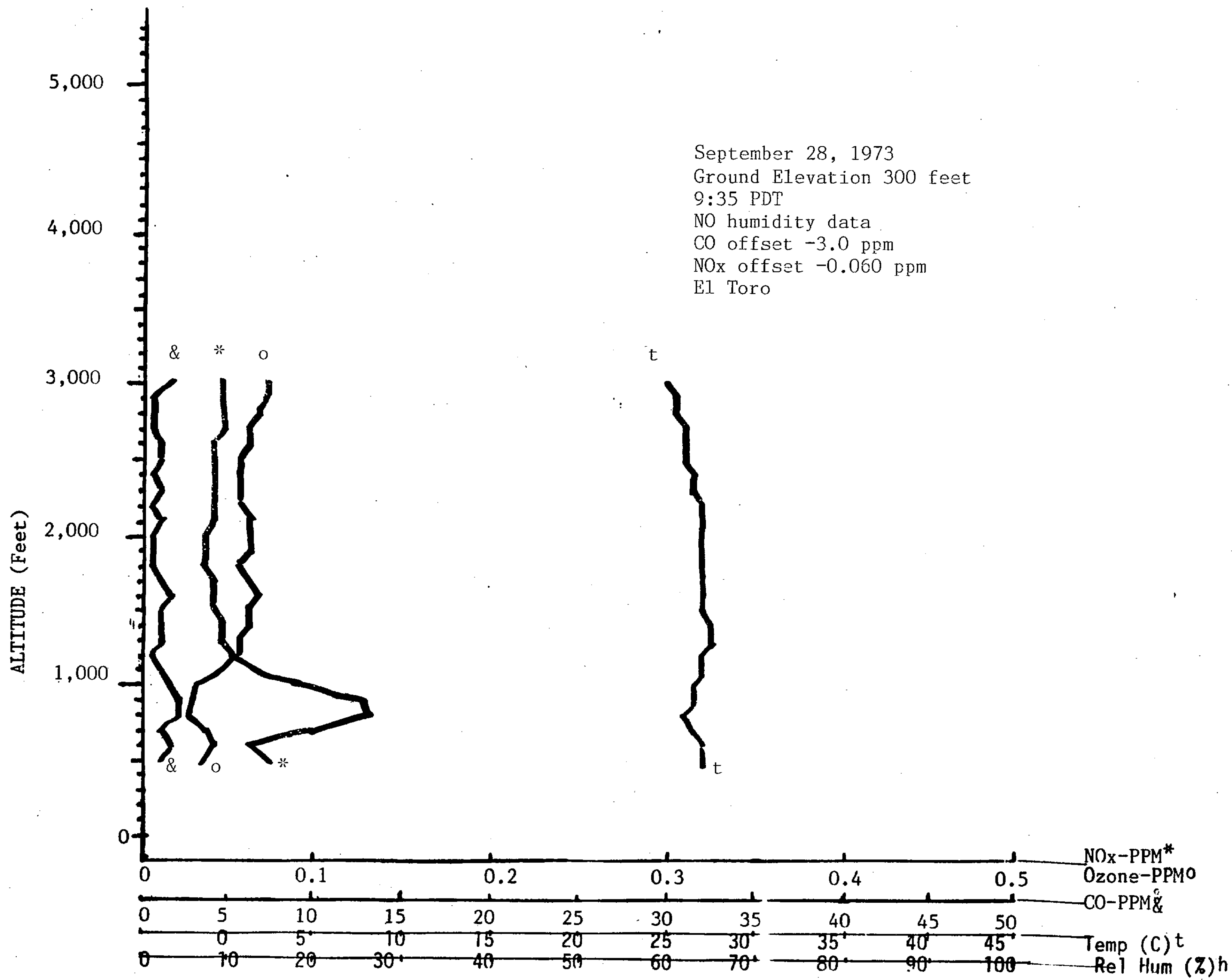
Date	Basin	Base	Aircraft	Route	Time (PDT)	Comments
8/16/73	L. A.	Cable	205	Riverside	0820-1032	CNM out in 205
				Riverside	1155-1358	VOR data questionable
				Riverside	1535-1735	NO_x out in 310; also
			310	Mountain-Desert	0829-1113	VOR and DME
				Mountain-Desert	1459-1715	
8/17/73	L. A.	Cable	205	Riverside	0817-1045	CO questionable in 205
				Riverside	1205-1407	
				Riverside	1616-1742	
			310	South	1201-1347	
				South	1625-1808	
			Navy van shut down by 1840			
8/22/73	L. A.		Navy van operating by 2050 at Brackett Airport			
8/23/73	L. A.	Cable	205	Riverside	0804-1002	NO_x sample pump out in 205
				Riverside	1200-1407	
				Riverside	1558-1753	
			310	South	0803-0959	
				South	1154-1323	
				South	1550-1753	
8/24/73	L. A.	Cable	205	Riverside	0805-0957	NO_x out in 205
				Riverside	1149-1342	CO, CNM out on Riverside route (1600-1752)
				Riverside	1600-1752	
			310	Mountain-Desert	0810-1012	
				Mountain-Desert	1348-1547	
			Navy van shut down by 1900			

Table D-2 (cont.)

Date	Basin	Base	Aircraft	Route	Time (PDT)	Comments
8/27/73	L. A.		Navy van operating by 0815			
			Navy van shut down by 1630			
8/28/73	L. A.	Cable	205	Riverside	0812-1234	NO_x cooler and data logger problems on 205
				Riverside	1606-1738	
			310	South	0813-1008	
				South	1214-1357	
				South	1602-1744	
8/30/73	L. A.	Cable	205	Special	1253-1436	Special flight
9/6/73	L. A.	Torrance	310	Special	1010-1142	Blimp flight #1
				Special	1400-1659	Blimp flight #2
9/13/73	L. A.		Navy van operating by 1443			
		Cable	205	Riverside	1401-1559	DME inoperative in 310
			310	Mountain-Desert	1143-1418	NO_x data questionable in 205
9/14/73	L. A.		Navy van shut down by 1900			
		Cable	205	Riverside	1307-1448	
				Riverside	1626-1825	
			310	North	1318-1541	
				North	1705-1826	
9/28/73	L. A.		Navy van operating by 1001 at Brackett Airport			
		Cable	205	Riverside	0817-1019	
				Riverside	1204-1408	
				Riverside	1556-1745	
			310	South	0804-0935	
				South	1157-1322	
				South	1533-1700	

Table D-2 (cont.)

Date	Basin	Base	Aircraft	Route	Time (PDT)	Comments
9/29/73	L. A.	Cable	205	South	0815-1022	Metronics tracer study day
				North	1200-1350	
				Riverside	1557-1750	
			310	North	0809-0943	
				South	1149-1329	
				North	1558-1720	
			Navy van shut down by 1800			
10/3/73	L. A.		Navy van operating by 1821			
		Cable	205	Special	0908-1103	
				Special	1453-1634	
			310	Special	0904-1122	Special flight
				Special	1456-1713	Upland-Freeway study
10/5/73	L. A.	Cable	205	Riverside	0825-1030	
				Riverside	1311-1438	
				Riverside	1707-1812	
			310	Special	1300-1415	Modified
				South	1619-1755	
			Navy van off by 1800			
11/6/73	L. A.		205	Special	1125-1225 PST	Freeway route
				Special	1401-1451 PST	Freeway route
				Special	1602-1646 PST	Freeway Route
1/9/74	Salinas	Salinas	205	Moss Landing Plume	1550-1740	Moss Landing Plume Study
1/10/74	Salinas	Salinas	205	Moss Landing Plume	0950-1150	
				Moss Landing Plume	1355-1545	



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CO offset -3.0 ppm
NOx offset -0.060 ppm
El Toro
& * o t
0 0.1 0.2 0.3 0.4 0.5 NOx-PPM*
Ozone-PPMo
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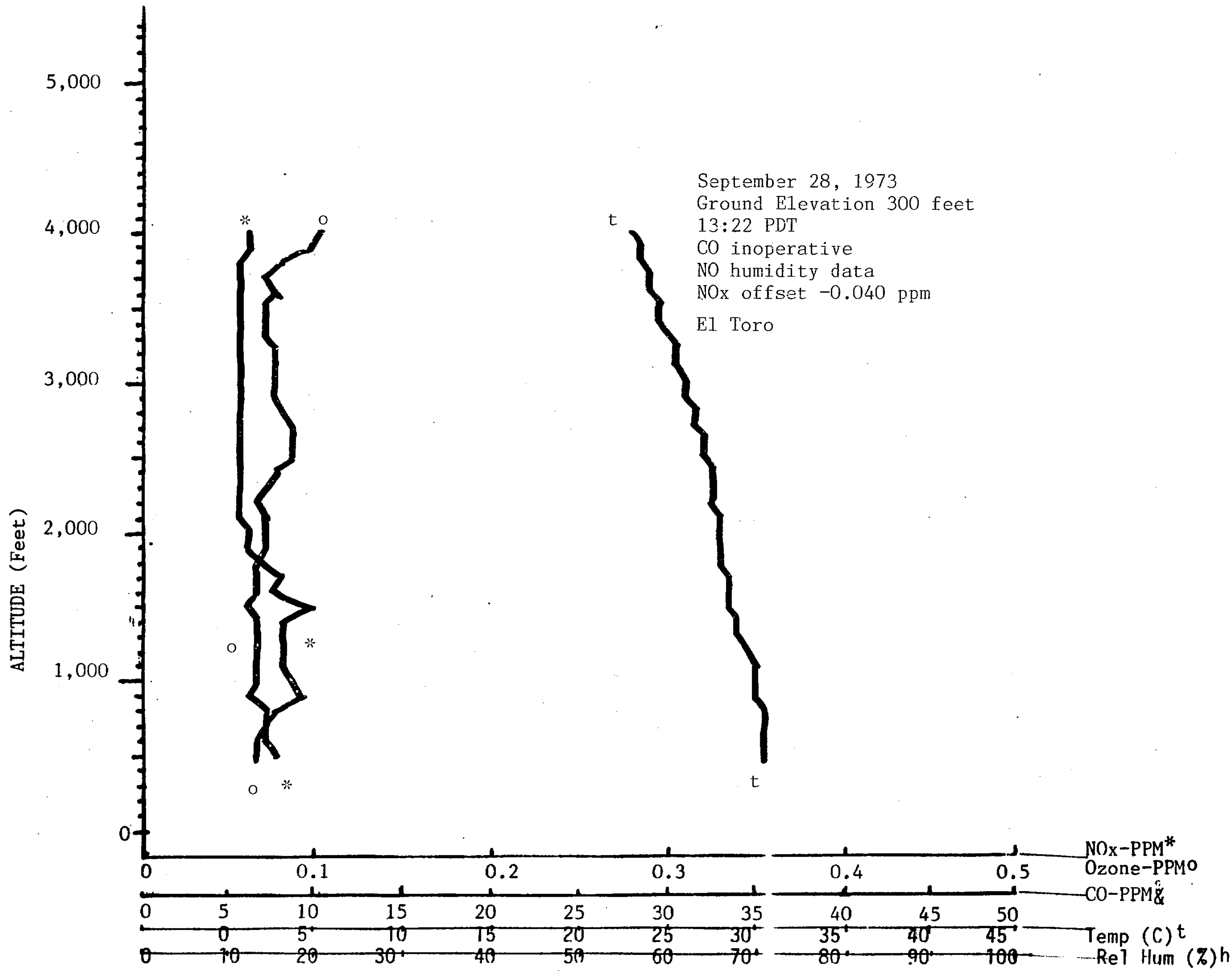
0 5 10 15 20 25 30 35 40 45 Temp (C)t
0 10 20 30 40 50 60 70 80 90 100 Rel Hum (%)h



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NOx-PPM*
Ozone-PPMo
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CO-PPM&
0 5 10 15 20 25 30 35 40 45
Temp (C)t
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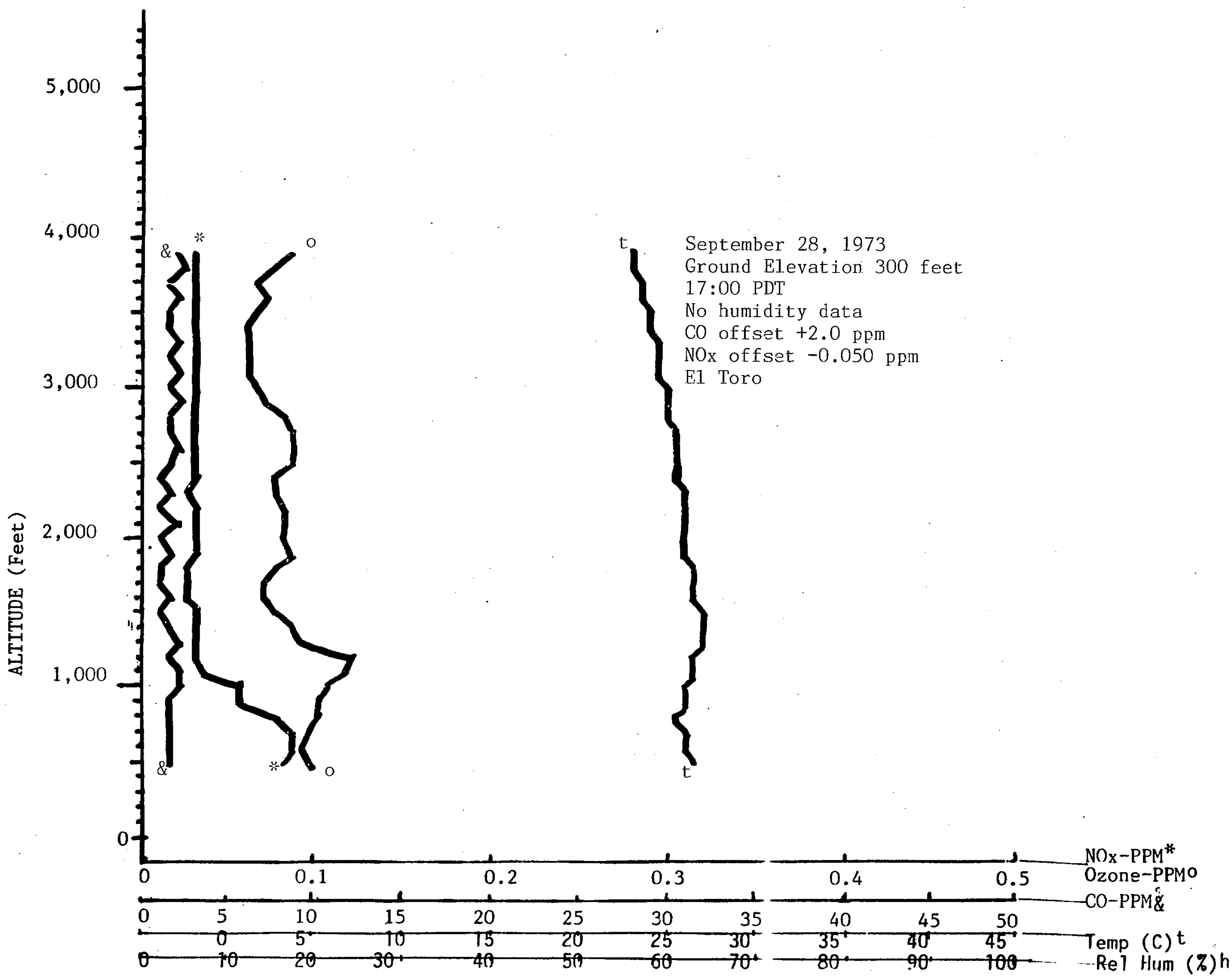
Rel Hum (%)h



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NOx offset -0.050 ppm
El Toro
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0
NOx-PPM*
Ozone-PPMo
CO-PPM&
Temp (C)t
Rel Hum (%)h
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0.1
0.2
0.3
0.4
0.5
0
5
10
15
20
25
30
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40
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90
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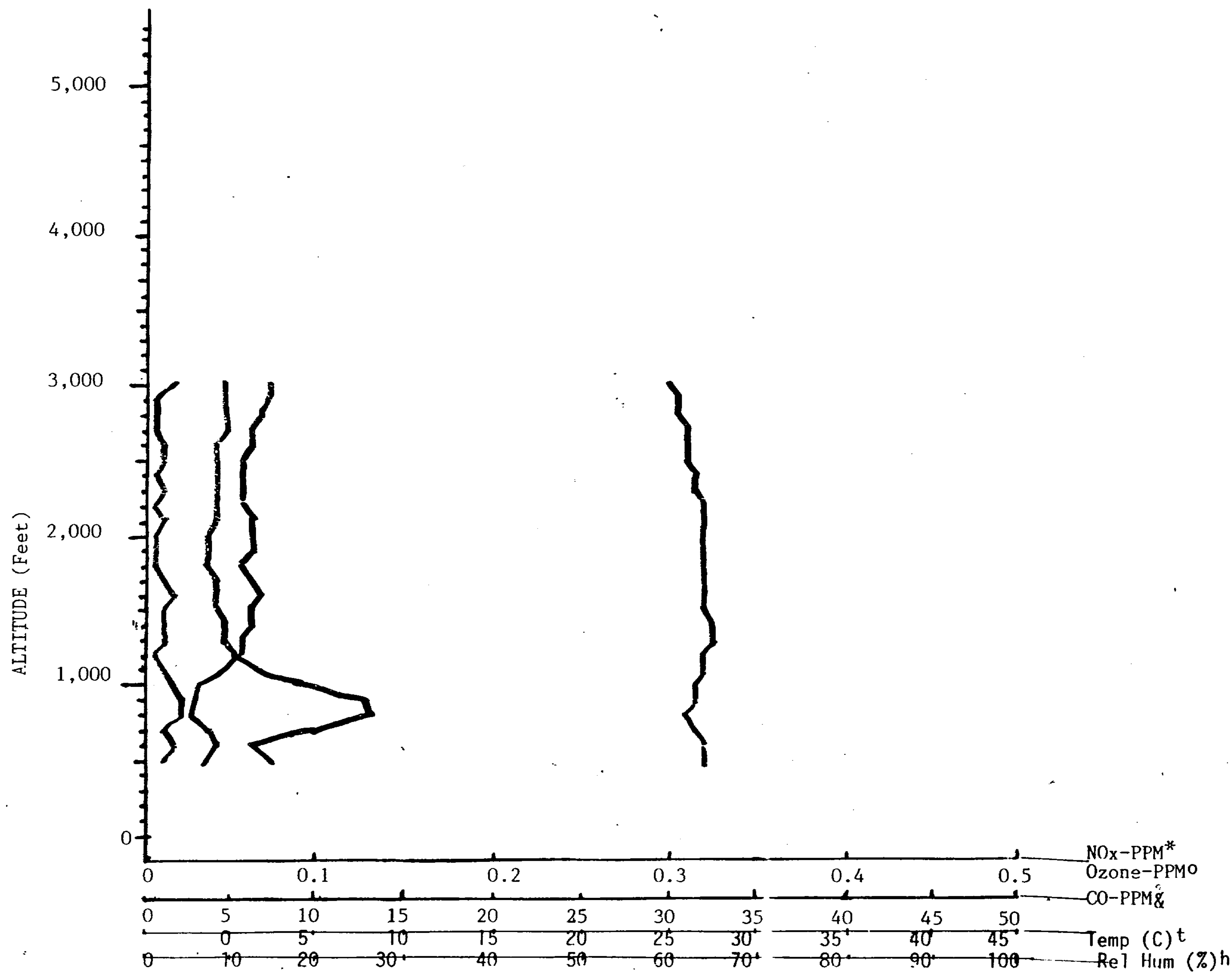

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NOx-PPM*
Ozone-PPMo
CO-PPM&
Temp (C)t
Rel Hum (%)h
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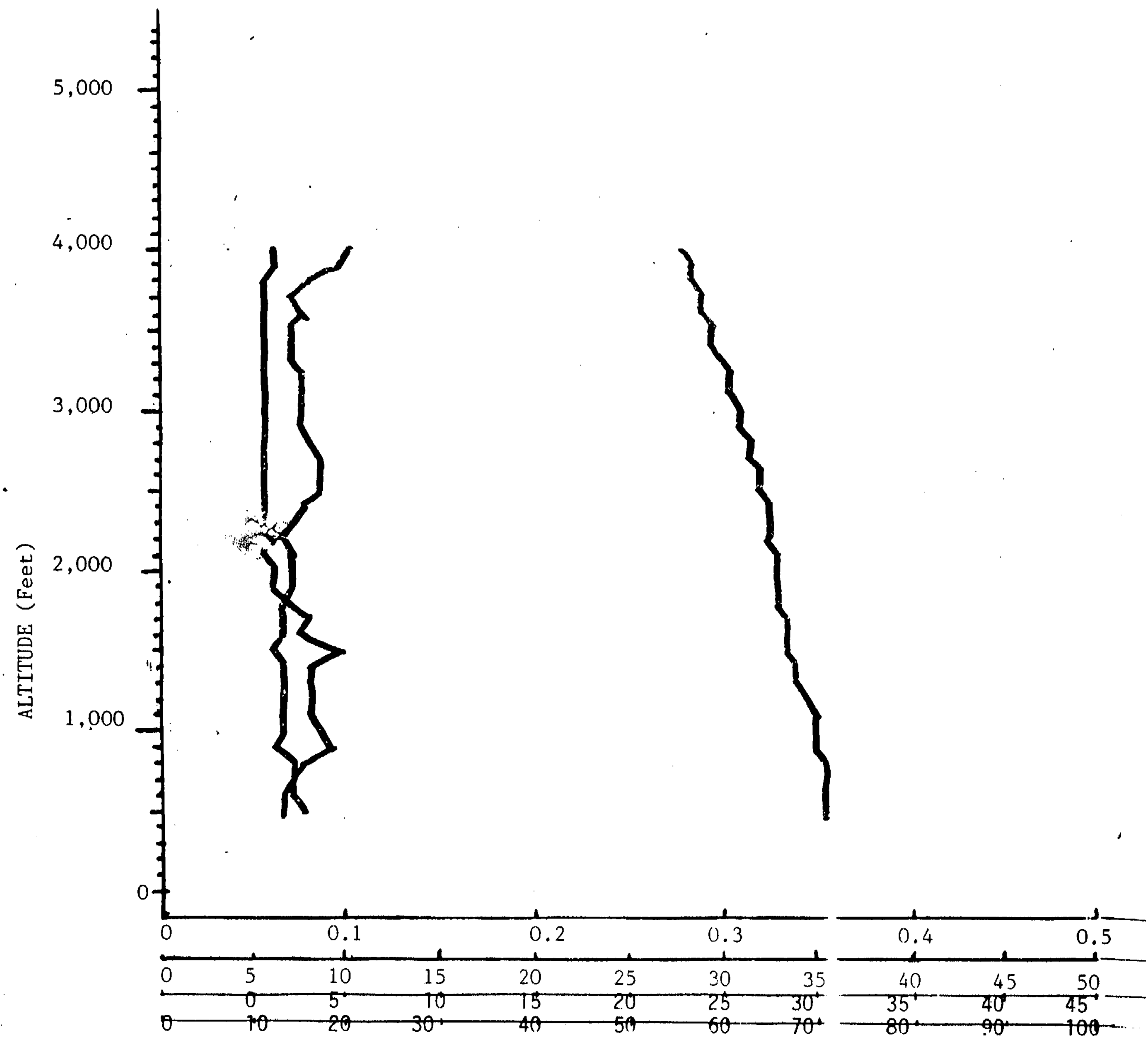
0 5 10 15 20 25 30 35 40 45
0 10 20 30 40 50 60 70 80 90 100



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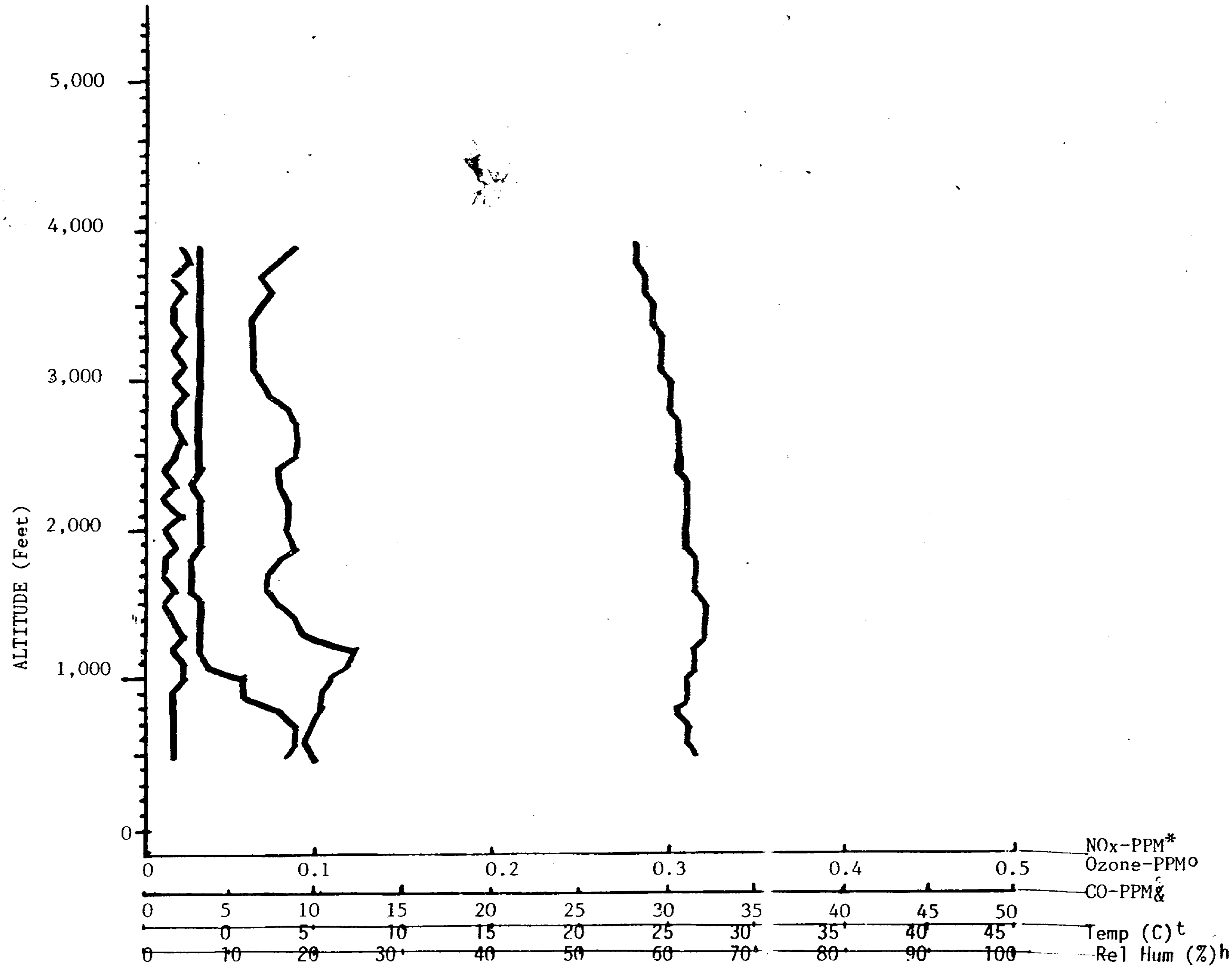
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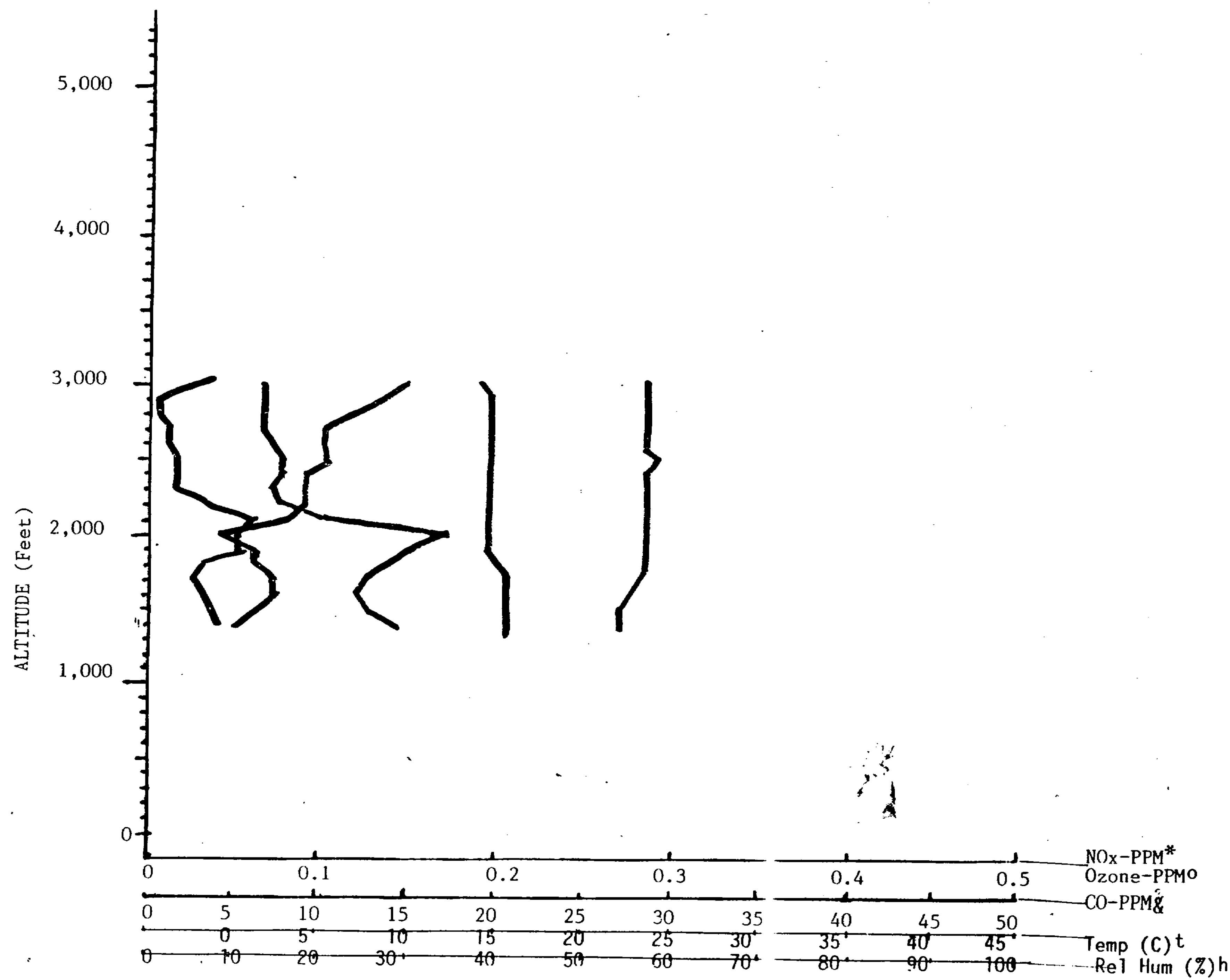
Ozone-PPMo
CO-PPM&
Temp (C)t
Rel Hum (%)h



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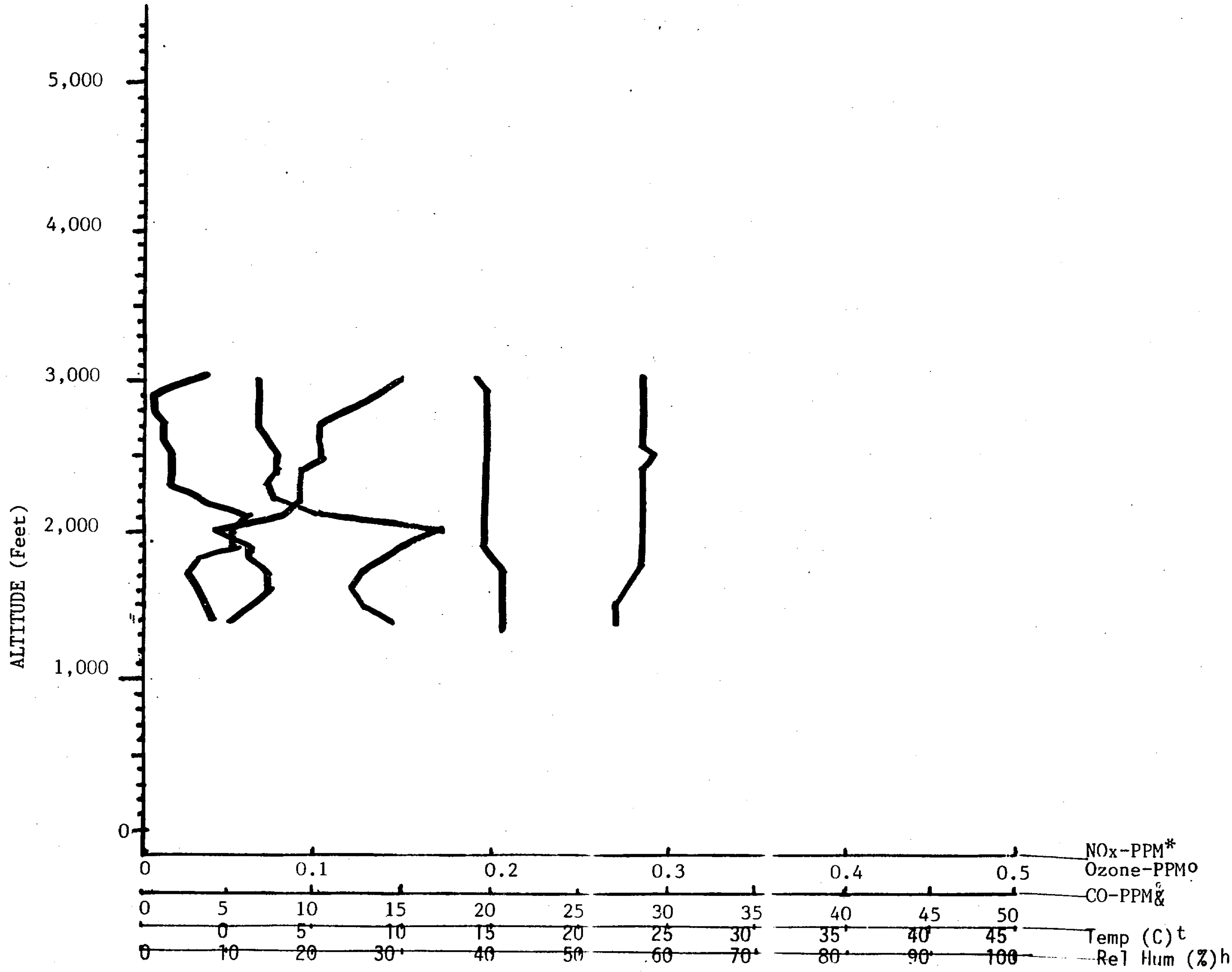
0 5 10 15 20 25 30 35 40 45
0 10 20 30 40 50 60 70 80 90 100
NOx-PPM*
Ozone-PPMo
CO-PPM&
Temp (C)t
Rel Hum (%)h



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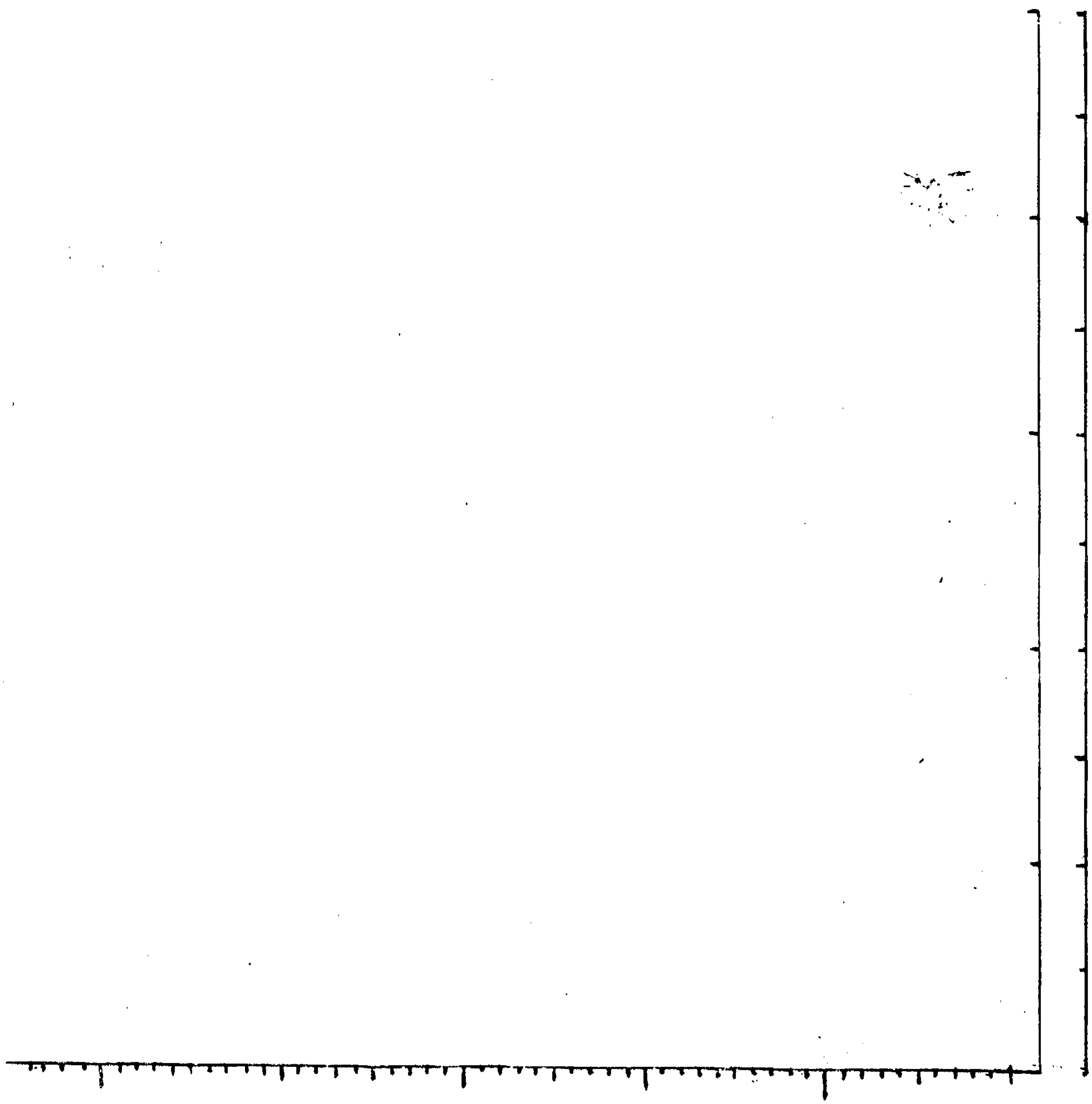
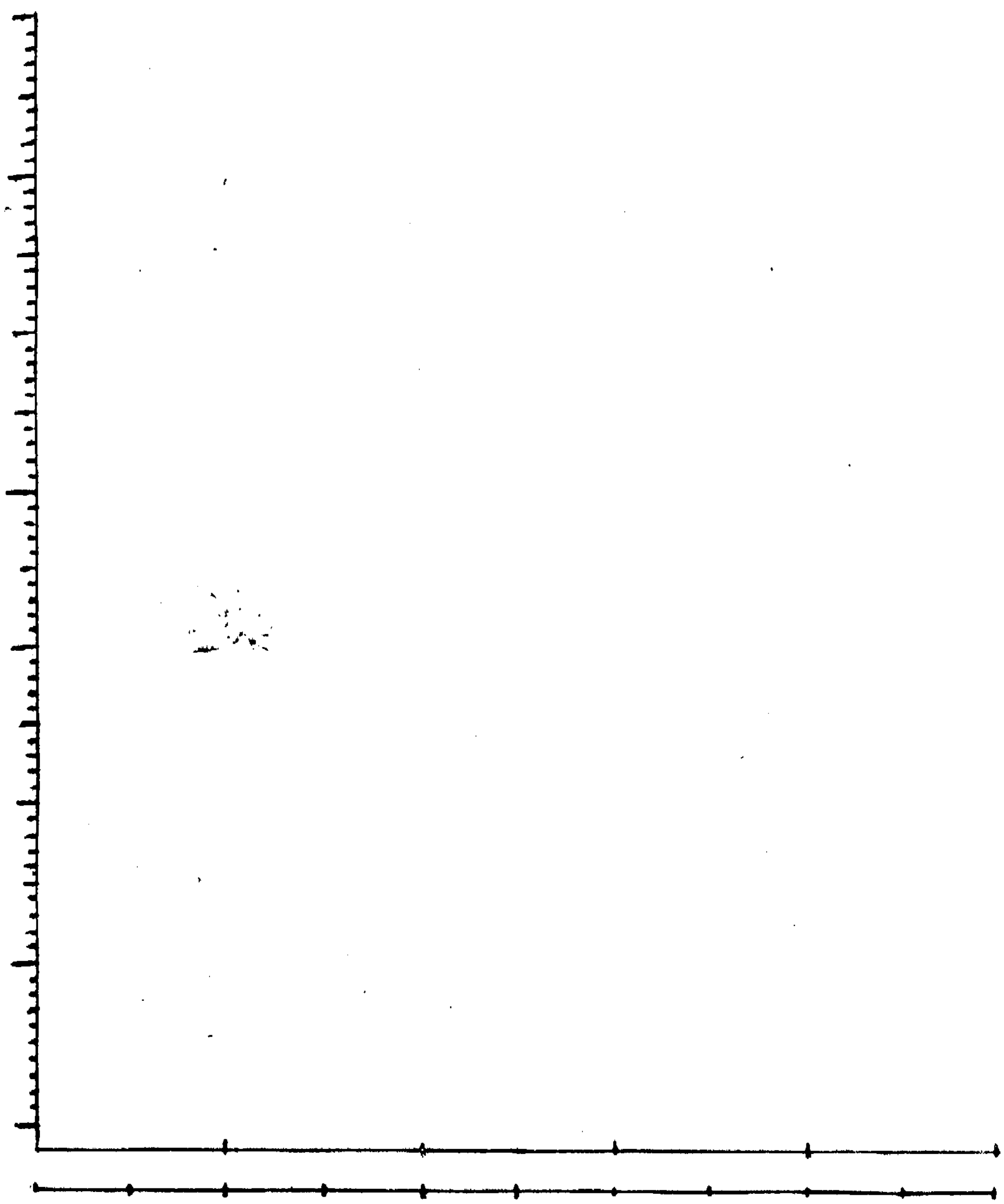
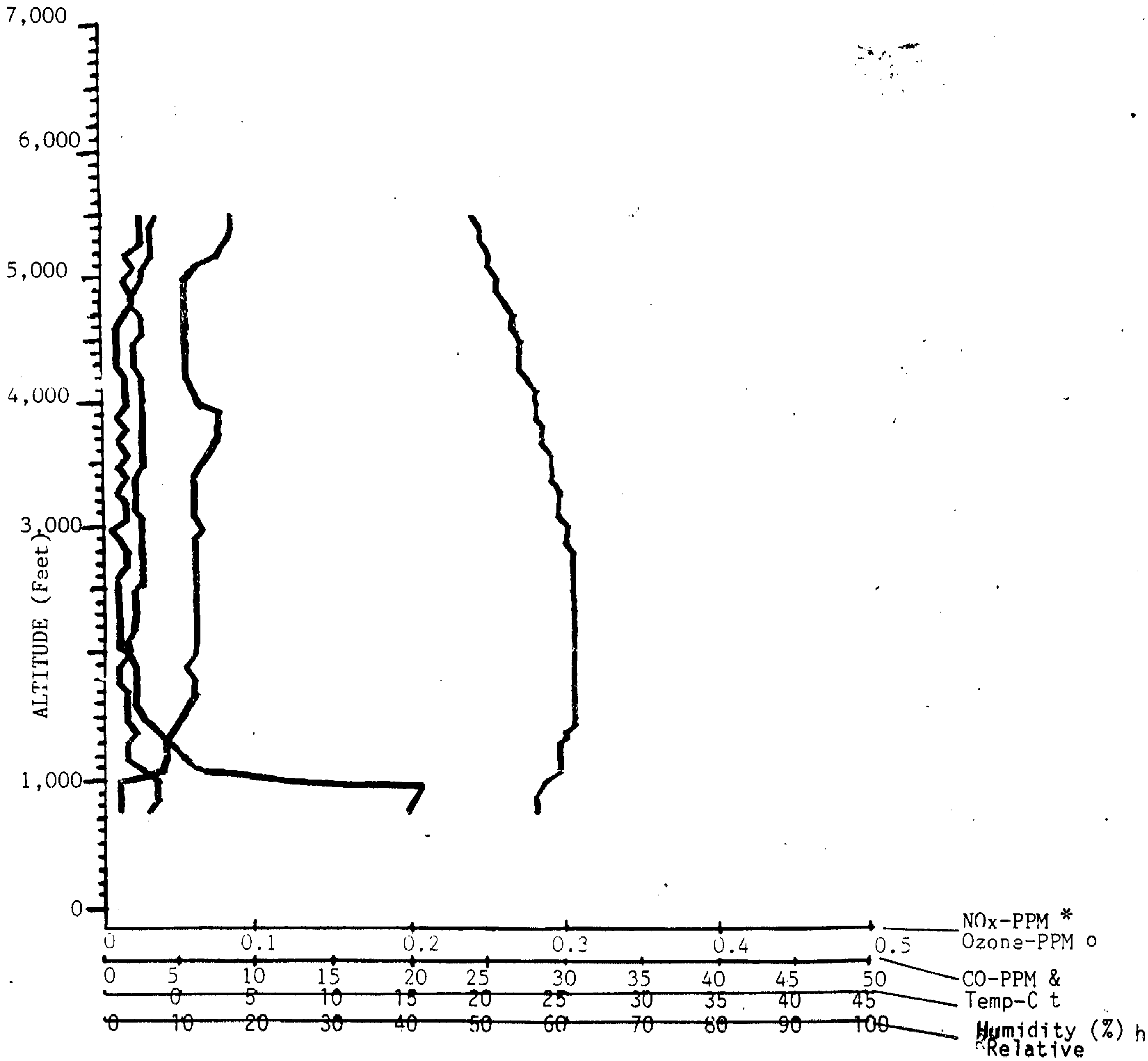
0 5 10 15 20 25 30 35 40 45
0 10 20 30 40 50 60 70 80 90 100
NOx-PPM*
Ozone-PPMo
CO-PPM&
Temp (C)t
Rel Hum (%)h



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NOx-PPM *
Ozone-PPM o
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CO-PPM &
0 5 10 15 20 25 30 35 40 45
Temp-C t
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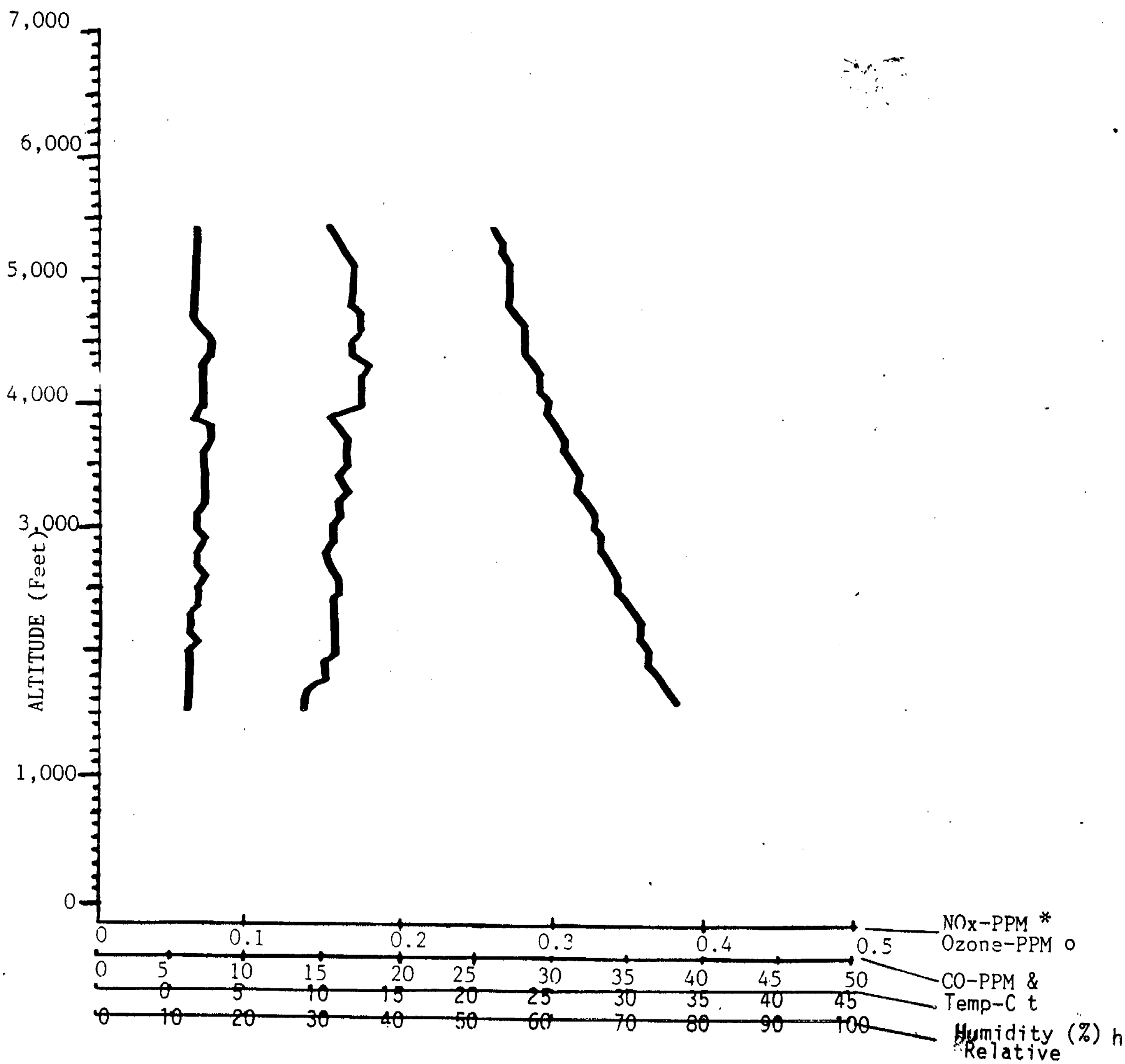
Relative Humidity (%) h



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NOx-PPM *
Ozone-PPM o
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CO-PPM &
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Temp-C t
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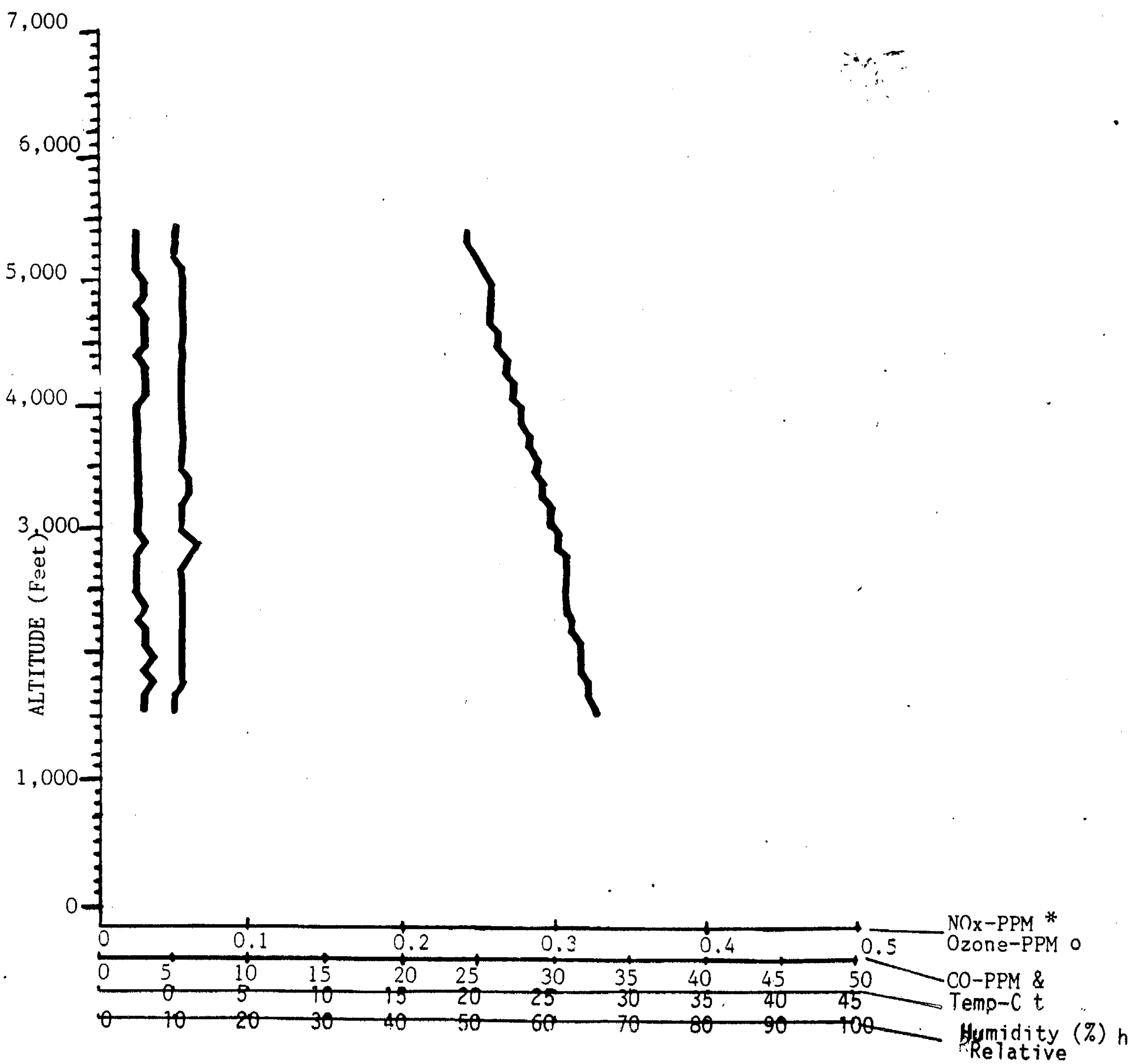
Humidity (%) h
Relative



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Ozone-PPM o
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CO-PPM &
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Temp-C t
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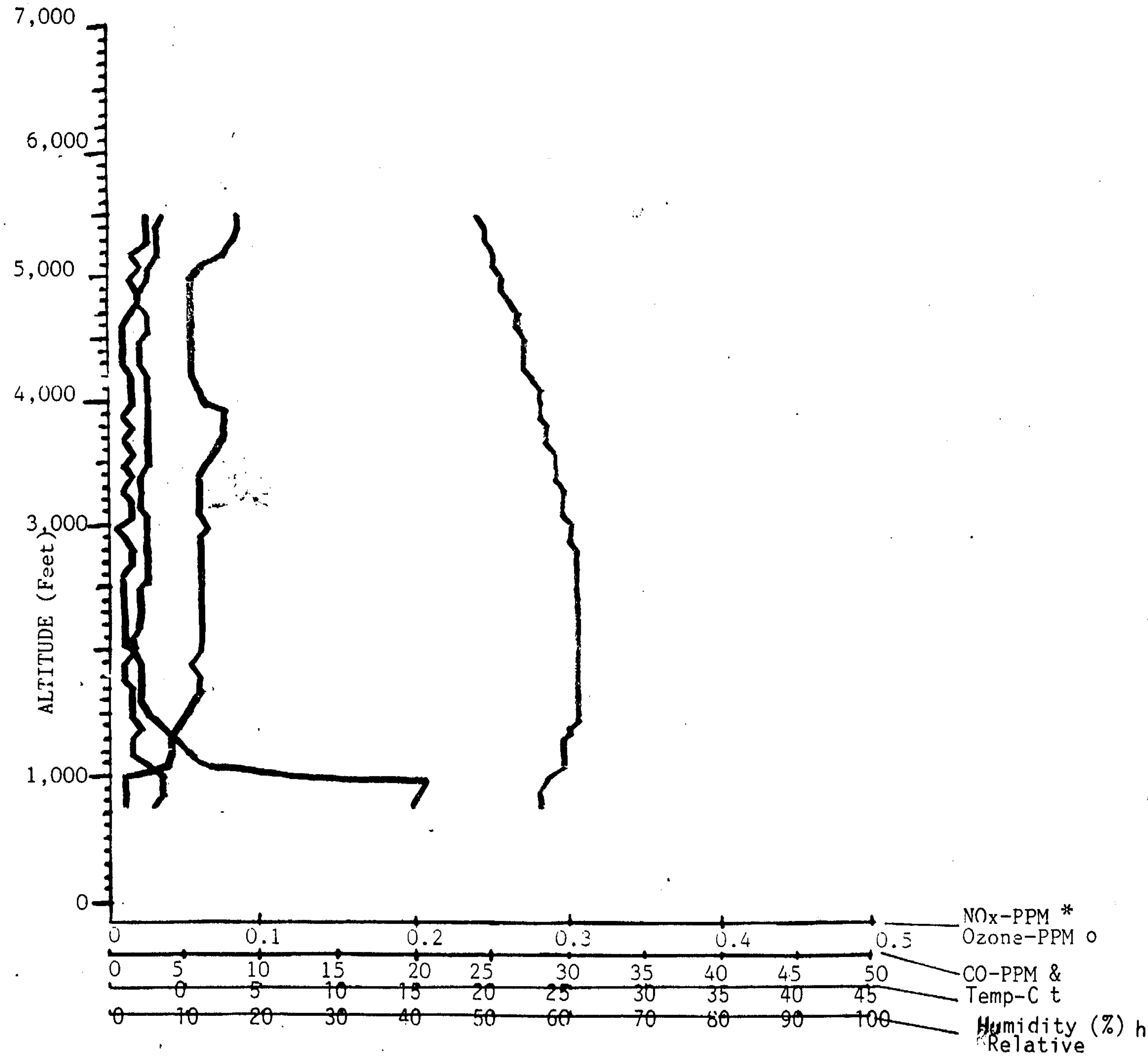
Relative Humidity (%) h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0 5 10 15 20 25 30 35 40 45 50
0 5 10 15 20 25 30 35 40 45
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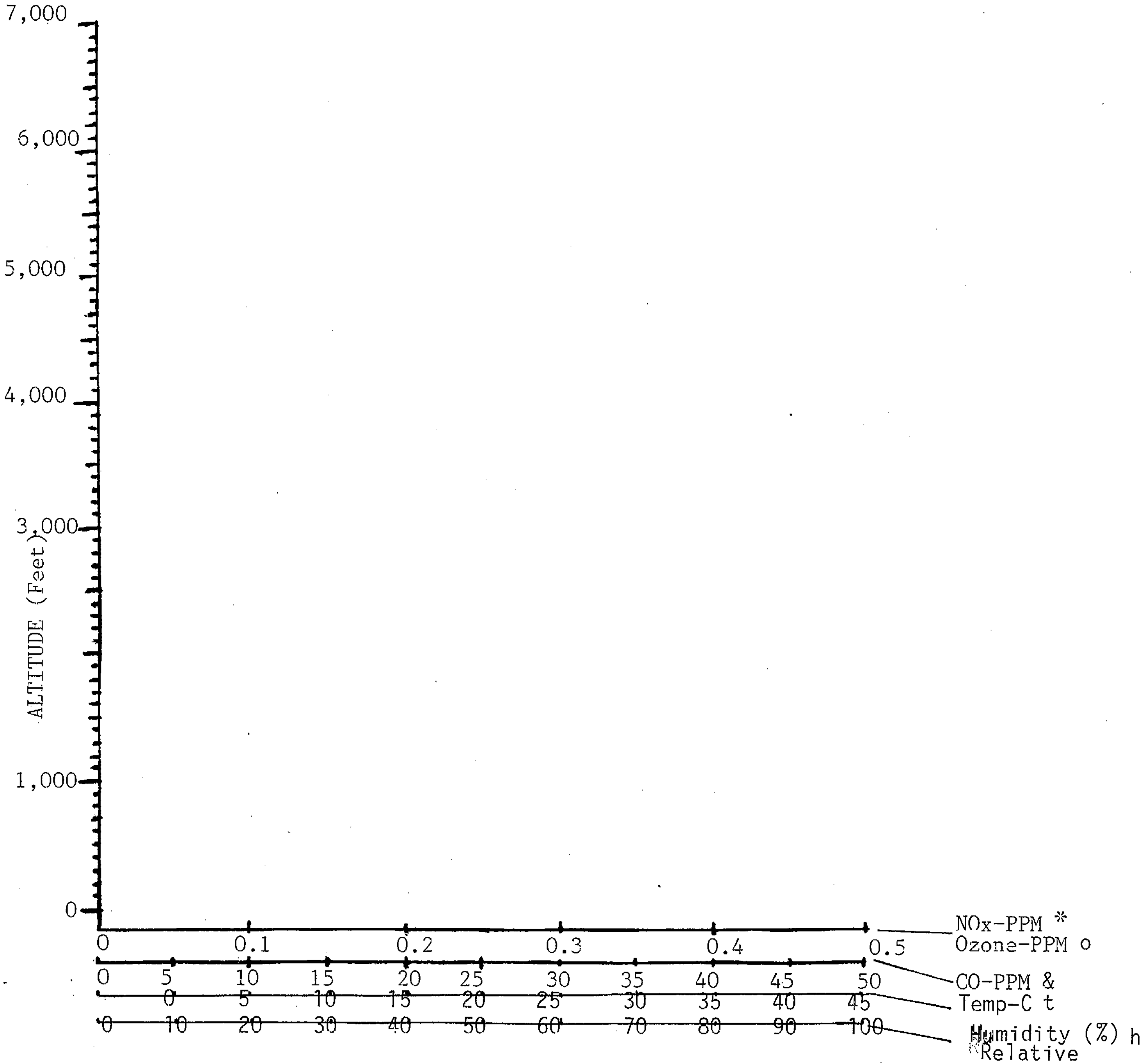
Ozone-PPM o
CO-PPM &
Temp-C t
Humidity (%) h
Relative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0 5 10 15 20 25 30 35 40 45
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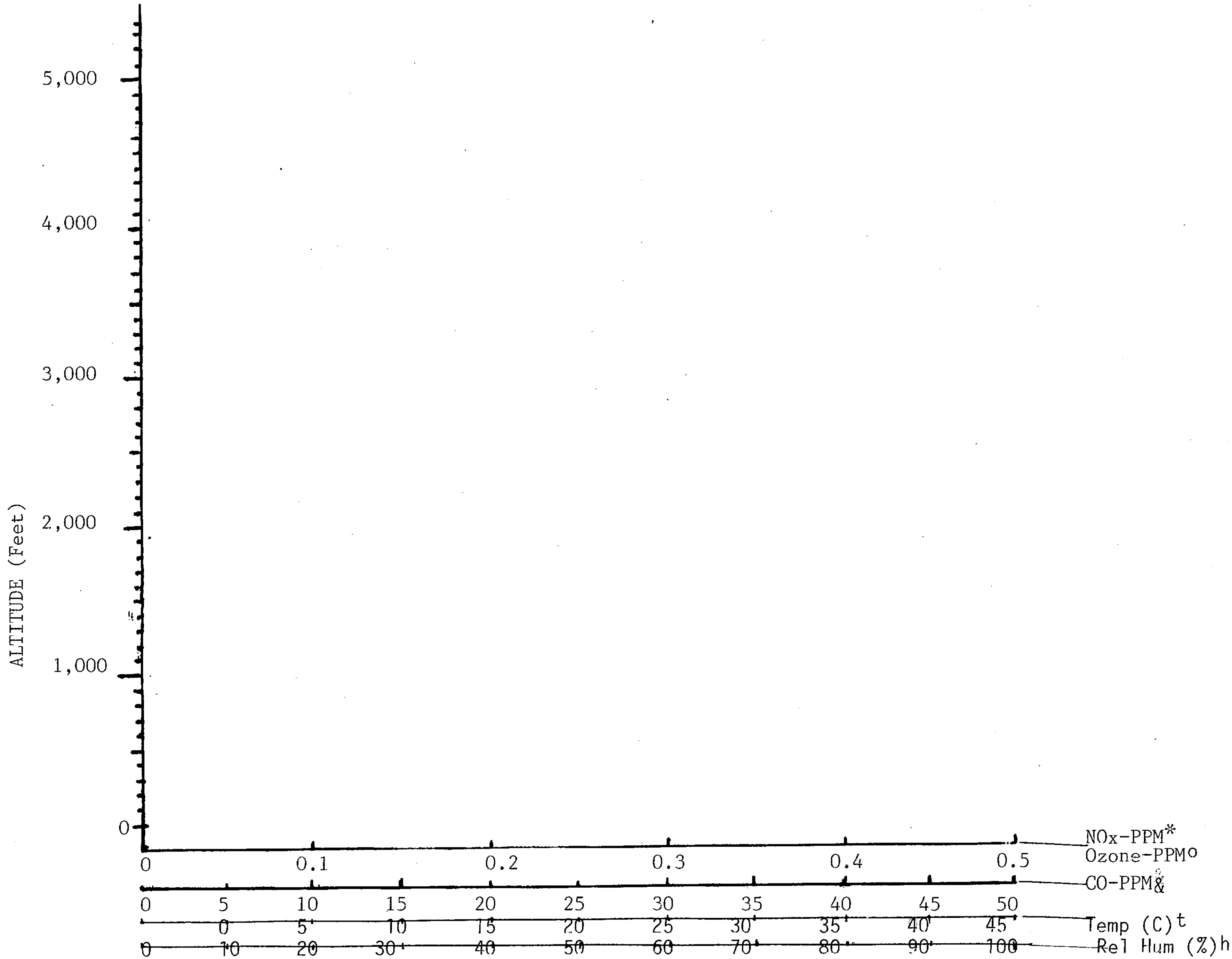
Ozone-PPM o
CO-PPM &
Temp-C t
Relative Humidity (%) h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0 10 20 30 40 50 60 70 80 90 100
NOx-PPM*
Ozone-PPMo
CO-PPM&
Temp (C)t
Rel Hum (%)h